



Clean Version

HIGH AFFINITY TGF β NUCLEIC ACID LIGANDS AND INHIBITORS

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RELATED APPLICATIONS

This application is a continuation of U.S. Patent Application Ser. No. 09/791,301, filed February 23, 2001, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 6,713,616, which is a continuation of U.S. Patent Application Serial No.

10 09/363,939, filed July 29, 1999, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 6,346,611, which is a continuation-in-part of U.S. Patent Application Ser. No. 09/046,247, filed March 23, 1998, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 6,124,449, which is a continuation-in-part of U.S. Patent Application Ser. No. 08/458,424, filed June 2, 1995, entitled "High Affinity TGF β

15 Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 5,731,424, which is a continuation-in-part of U.S. Patent Application Ser. No. 07/714,131, filed June 10, 1991, entitled "Nucleic Acid Ligands," now U.S. Patent No. 5,475,096, which is a continuation-in-part of U.S. Patent Application Serial No. 07/536,428, filed June 11, 1990, entitled "Systematic Evolution of Ligands by EXponential Enrichment," now abandoned. U.S. Patent Application Ser. No.

20 08/458,424 is also a continuation in part of U.S. Patent Application Ser. No. 07/931,473, filed August 17, 1992, entitled "Methods for Identifying Nucleic Acid Ligands," now U.S. Patent No. 5,270,163. U.S. Patent Application Ser. No. 08/458,424 is also a continuation in part of U.S. Patent Application Ser. No. 07/964,624, filed October 21, 1992, entitled " Nucleic Acid Ligands to HIV-RT and HIV-1 Rev," now U.S. Patent No. 5,496,938. U.S. Patent Application Ser. No.

25 08/458,424 is also a continuation in part of U.S. Patent Application Serial No. 08/117,991, filed September 8, 1993, entitled "High Affinity Nucleic Acid Ligands Containing Modified Nucleotides," now abandoned. U.S. Patent Application Ser. No. 09/363,939 is also a continuation-in-part of U.S. Patent Application Ser. No. 08/434,465, entitled "Nucleic Acid Ligand Complexes," filed May 4, 1995, now U.S. Patent No. 6,011,020. The disclosure of each

30 of the foregoing applications, and all patents and publications referred to herein, is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

Described herein are methods for identifying and preparing high affinity nucleic acid ligands that bind human transforming growth factor β 2 (TGF β 2). The method utilized herein for identifying such nucleic acid ligands is called SELEX, an acronym for Systematic Evolution of Ligands by EXponential Enrichment. This invention includes high affinity nucleic acids of human TGF β 2. Further disclosed are RNA ligands to TGF β 2. Also included are oligonucleotides containing nucleotide derivatives modified at the 2' position of the pyrimidines. Additionally disclosed are ligands to TGF β 2 containing 2'-OCH₃ purine modifications that may have higher stability in serum and in animals. This invention also includes high affinity nucleic acid inhibitors of TGF β 2. The oligonucleotide ligands of the present invention are useful in any process in which binding to TGF β 2 is required. This includes, but is not limited to, their use as pharmaceuticals, diagnostics, imaging agents, and immunohistochemical reagents.

BACKGROUND OF THE INVENTION

Transforming growth factors betas (TGF β s) are part of a superfamily of proteins that includes inhibins, activins, bone morphogenetic and osteogenic proteins, growth/differentiation factors, Mullerian-inhibiting substance, decapentaplegic and 60A (*Drosophila*), daf-7 and unc-129 (*C. elegans*), and vgl (*Xenopus*) (Schlueneger and Grutter (1992) *Nature* 358:430-434). Three TGF β isotypes exist in mammals that are called TGF β 1, TGF β 2, and TGF β 3. There is about 80% sequence identity between any pair of mammalian TGF β s. TGF β s bind to at least 5 receptors, but only 2 or 3 of them (types I, II, and possibly V) are signaling receptors. The intracellular signaling pathways activated by TGF β s involve SMAD proteins and are being intensively studied (Padgett et al. (1998) *Pharmacol Ther* 78:47-52). The signaling receptors are found on a variety of cells. In turn, a variety of cells express TGF β s.

TGF β s are synthesized as precursors composed of latency-associated protein (LAP) at the amino terminus and mature TGF β at the carboxyl terminus. The precursor is cleaved and assembles as a homodimer. TGF β s are secreted from cells bound to LAP and latent TGF β binding proteins (LTBPs). Latent TGF β s are released from LAP and LTPB and become active by a relatively uncharacterized mechanism that may involve proteolysis by plasmin or regulation by thrombospondin (Crawford et al. (1998) *Cell* 93:1159-70). The mature, released TGF β

homodimer has a combined molecular weight of ~25000 daltons (112 amino acids per monomer). TGF β 1 and TGF β 2 bind heparin and there are indications that basic amino acids at position 26 are required for heparin binding (Lyon et al. (1997) *Jour. Biol. Chem.* 272:18000-18006).

5 The structure of TGF β 2 has been determined using x-ray crystallography (Daopin et al. (1992) *Science* 257:369-373; Schlunegger and Grutter (1992) *Nature* 358:430-434) and is very similar to the structure of TGF β 1. TGF β s belong to a structural family of proteins called the "cysteine knot" proteins that includes vascular endothelial growth factor, nerve growth factor, human chorionic gonadotropin, and platelet-derived growth factor. These proteins are 10 structurally homologous, but have only 10-25% primary sequence homology.

The biological activities of the TGF β s vary (Moses (1990) *Growth Factors from Genes to Clinical Application* 141-155; Wahl (1994) *J. Exp. Med.* 180:1587-1590). In some cases they inhibit cell proliferation (Robinson et al. (1991) *Cancer Res.* 113:6269-6274) and in other cases they stimulate it (Fynan and Reiss (1993) *Crit. Rev. Oncogenesis* 4:493-540). They regulate 15 extracellular matrix formation and remodeling (Koli and Arteaga (1996) *J. Mammary Gland Bio.* and *Neoplasia* 1:373-380). They are also are very potent immunosuppressants (Letterio and Roberts (1998) *Ann. Rev. Immunol.* 16:137-161). TGF β s are thought to play a significant role in fibrotic diseases, preventing the immune system from rejecting tumors (Fakhrai et al. (1996) *Proc. Natl. Acad. USA* 93:2090-2914), cancer cell growth (Koli and Arteaga (1996) *J. Mammary 20 Gland Bio. and Neoplasia* 1:373-380; Reiss and Barcellos-Hoff (1997) *Breast Cancer Res. and Treatment* 45:81-85; Jennings and Pietenpol (1998) *J. Neurooncol.* 36:123-140), and tumor 25 metastasis. They may have ancillary roles in autoimmune and infectious diseases. Inhibition of TGF β 2 by an expressed antisense RNA (Fakhrai et al. (1996) *Proc. Natl. Acad. USA* 93:2090-2914) and by exogenous antisense oligonucleotides (Marzo et al. (1997) *Cancer Research* 57:3200-3207) has been reported to prevent glioma formation in rats.

The gene for mouse TGF β 2 has been deleted (Sanford et al. (1997) *Development* 124:2659-2670). Mice lacking TGF β 2 function die near birth and have aberrant epithelial-mesencymal interactions that lead to developmental defects in the heart, eye, ear, lung, limb, craniofacial area, spinal cord, and urogenital tracts. These defects, for the most part, do not 30 overlap abnormalities that have been observed in TGF β 1 and TGF β 3 knockout mice. TGF β s

have also been overexpressed in cell lines or transgenic mice (Koli and Arteaga (1996) J. Mammary Gland Bio. and Neoplasia 1:373-380; Bottinger et al. 1997 Kidney Int. 51:1355-1360; Bottinger and Kopp (1998) Miner Electrolyte Metab 24:154-160) with a variety of effects.

A method for the *in vitro* evolution of nucleic acid molecules with high affinity binding to target molecules has been developed. This method, Systematic Evolution of Ligands by Exponential enrichment, termed SELEX, is described in U.S. Patent Application Serial No. 07/536,428, filed June 11, 1990, entitled "Systematic Evolution of Ligands by Exponential Enrichment," now abandoned, U.S. Patent Application Serial No. 07/714,131, filed June 10, 1991, entitled "Nucleic Acid Ligands," now U.S. Patent No. 5,475,096 and U.S. Patent Application Serial No. 07/931,473, filed August 17, 1992, entitled "Methods for Identifying Nucleic Acid Ligands," now U.S. Patent No. 5,270,163 (see also WO91/19813), each of which is herein specifically incorporated by reference. Each of these applications, collectively referred to herein as the SELEX Patent Applications, describe a fundamentally novel method for making a nucleic acid ligand to any desired target molecule.

The SELEX method involves selection from a mixture of candidate oligonucleotides and step-wise iterations of binding, partitioning and amplification, using the same general selection theme, to achieve virtually any desired criterion of binding affinity and selectivity. Starting from a mixture of nucleic acids, preferably comprising a segment of randomized sequence, the SELEX method includes steps of contacting the mixture with the target under conditions favorable for binding, partitioning unbound nucleic acids from those nucleic acids which have bound to target molecules, dissociating the nucleic acid-target complexes, amplifying the nucleic acids dissociated from the nucleic acid-target complexes to yield a ligand-enriched mixture of nucleic acids, then reiterating the steps of binding, partitioning, dissociating and amplifying through as many cycles as desired to yield high affinity nucleic acid ligands to the target molecule.

The basic SELEX method may be modified to achieve specific objectives. For example, U.S. Patent Application Serial No. 07/960,093, filed October 14, 1992, entitled "Method for Selecting Nucleic Acids on the Basis of Structure," now abandoned, describes the use of SELEX in conjunction with gel electrophoresis to select nucleic acid molecules with specific structural characteristics, such as bent DNA (See U.S. Patent No. 5,707,796). U.S. Patent Application Serial No. 08/123,935, filed September 17, 1993, entitled "Photoselection of Nucleic Acid

Ligands," now abandoned, describes a SELEX based method for selecting nucleic acid ligands containing photoreactive groups capable of binding and/or photocrosslinking to and/or photoinactivating a target molecule. U.S. Patent Application Serial No. 08/134,028, filed October 7, 1993, entitled "High-Affinity Nucleic Acid Ligands That Discriminate Between

5 Theophylline and Caffeine," now abandoned, describes a method for identifying highly specific nucleic acid ligands able to discriminate between closely related molecules, termed "Counter-SELEX" (See U.S. Patent No. 5,580,737). U.S. Patent Application Serial No. 08/143,564, filed October 25, 1993, entitled "Systematic Evolution of Ligands by EXponential Enrichment: Solution SELEX," now abandoned, (See also U.S. Patent No. 5,567,588) and U.S. Patent

10 Application Serial No. 08/792,075, filed January 31, 1997, entitled "Flow Cell SELEX," now U.S. Patent No. 5,861,254, describe SELEX-based methods which achieve highly efficient partitioning between oligonucleotides having high and low affinity for a Target molecule. U.S. Patent Application Serial No. 07/964,624, filed October 21, 1992, entitled " Nucleic Acid Ligands to HIV-RT and HIV-1 Rev," now U.S. Patent No. 5,496,938, describes methods for

15 obtaining improved Nucleic Acid Ligands after the SELEX process has been performed. U.S. Patent Application Serial No. 08/400,440, filed March 8, 1995, entitled "Systematic Evolution of Ligands by EXponential Enrichment: Chemi-SELEX," now U.S. Patent No. 5,705,337,describes methods for covalently linking a ligand to its target.

The SELEX method encompasses the identification of high-affinity nucleic acid ligands

20 containing modified nucleotides conferring improved characteristics on the ligand, such as improved *in vivo* stability or delivery. Examples of such modifications include chemical substitutions at the ribose and/or phosphate and/or base positions. Specific SELEX-identified nucleic acid ligands containing modified nucleotides are described in U.S. Patent Application Serial No. 08/117,991, filed September 8, 1993, entitled "High Affinity Nucleic Acid Ligands

25 Containing Modified Nucleotides," now abandoned, that describes oligonucleotides containing nucleotide derivatives chemically modified at the 5- and 2'-positions of pyrimidines, as well as specific RNA ligands to thrombin containing 2'-amino modifications (See U.S. Patent No. 5,660,985). U.S. Patent Application Serial No. 08/134,028, *supra*, describes highly specific nucleic acid ligands containing one or more nucleotides modified with 2'-amino (2'-NH₂), 2'-fluoro (2'-F), and/or 2'-O-methyl (2'-OMe). U.S. Patent Application Serial No. 08/264,029, filed

June 22, 1994, entitled "Novel Method of Preparation of Known and Novel 2' Modified Nucleosides by Intramolecular Nucleophilic Displacement," now abandoned, describes oligonucleotides containing various 2'-modified pyrimidines. PCT/US98/00589 (WO 98/18480), filed January 7, 1998, entitled "Bioconjugation of Oligonucleotides" describes a method for 5 identifying bioconjugates to a target comprising nucleic acid ligands derivatized with a molecular entity exclusively at the 5'-position of the nucleic acid ligands.

The SELEX method encompasses combining selected oligonucleotides with other selected oligonucleotides and non-oligonucleotide functional units as described in U.S. Patent Application Serial No. 08/284,063, filed August 2, 1994, entitled "Systematic Evolution of 10 Ligands by Exponential Enrichment: Chimeric SELEX," now U.S. Patent No. 5,637,459 and U.S. Patent Application Serial No. 08/234,997, filed April 28, 1994, entitled "Systematic Evolution of Ligands by Exponential Enrichment: Blended SELEX," now U.S. Patent No. 5,683,867, respectively. These applications allow the combination of the broad array of shapes and other properties, and the efficient amplification and replication properties, of 15 oligonucleotides with the desirable properties of other molecules. The full text of the above described patent applications, including but not limited to, all definitions and descriptions of the SELEX process, are specifically incorporated herein by reference in their entirety.

BRIEF SUMMARY OF THE INVENTION

20 The present invention includes methods of identifying and producing nucleic acid ligands to transforming growth factor beta (TGF β 2) and the nucleic acid ligands so identified and produced. In particular, RNA sequences are provided that are capable of binding specifically to TGF β 2. Also included are oligonucleotides containing nucleotide derivatives modified at the 2' position of the pyrimidines. Specifically included in the invention are the RNA ligand sequences 25 shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193). Also included in this invention are RNA ligands of TGF β 2 that inhibit the function of TGF β 2. Also described herein are 2'-OMe-modified nucleic acid ligands of TGF β 1, shown in **Table 22** (SEQ ID NOS:194-216).

30 Further included in this invention is a method of identifying nucleic acid ligands and nucleic acid ligand sequences to TGF β 2, comprising the steps of (a) preparing a candidate

mixture of nucleic acids, (b) contacting the candidate mixture of nucleic acids with TGF β 2, (c) partitioning between members of said candidate mixture on the basis of affinity to TGF β 2, and (d) amplifying the selected molecules to yield a mixture of nucleic acids enriched for nucleic acid sequences with a relatively higher affinity for binding to TGF β 2.

5 More specifically, the present invention includes the RNA ligands to TGF β 2, identified according to the above-described method, including those ligands shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193). Also included are nucleic acid ligands to TGF β 2 that are substantially homologous to any of the given ligands and that have substantially the same ability to bind TGF β 2 and inhibit the function of TGF β 2. Further 10 included in this invention are nucleic acid ligands to TGF β 2 that have substantially the same structural form as the ligands presented herein and that have substantially the same ability to bind TGF β 2 and inhibit the function of TGF β 2.

The present invention also includes other modified nucleotide sequences based on the nucleic acid ligands identified herein and mixtures of the same.

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BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a flow chart summarizing the various SELEX experiments done with TGF β 2. The length of the arrowheads corresponds to the round number shown to the left. Connected arrowheads indicate branches in the SELEX experiments where a pool was used to 20 start a new branch. Under each arrowhead the fold improvement in affinity is also shown.

Figure 2 shows activity of TGF β 2 following amine coupling on a BIAcore carboxymethylcellulose (CM5) chip. A CM5 chip was loaded with TGF β 2 using NHS-EDC coupling as described in the Materials and Methods at about 18, 718, and 1692 response units for flow cell (FC) 1, 2, and 3, respectively. FC-4 was left blank as a control and was used to 25 normalize the signals from the other FCs. The chip was then exposed to 10 nM of either (Figure 2A) latency associated peptide (LAP) or (Figure 2B) TGF β soluble receptor III (sRIII) at 20 μ l/min in binding buffer. Data were collected for an association and a dissociation phase as shown. The signal from FC-4 was subtracted from the other FCs.

Figure 3 shows affinity improvement during the spr SELEX. A CM5 chip was loaded 30 with TGF β 2 using NHS-EDC coupling as described in the Materials and Methods at about 18,

718, and 1692 response units for flow cell (FC) 1, 2, and 3, respectively. FC-4 was left blank as a control and was used to normalize the signals from the other FCs. The chip was then exposed to 1 :M of RNA pools from the SELEX rounds (Rd) as shown at 20 :l/min in binding buffer. Data were collected for an association and a dissociation phase as shown. The signal from FC-4
5 was subtracted from the other FCs.

Figure 4 shows nitrocellulose filter binding curves with pools from the spr SELEX. High specific activity internally labeled RNA was used from rounds (R) as shown. Labeled RNA was incubated with various concentrations of TGF β 2 in the presence of ~100,000 fold molar excess unlabelled tRNA. Bound RNA was partitioned by nitrocellulose filtration and
10 quantitated. Data were analyzed as described in the Materials and Methods.

Figure 5 shows nitrocellulose filter binding curves with various pools. High specific activity internally labeled RNA was used from rounds (R) as shown. Labeled RNA was incubated with various concentrations of TGF β 2 (no competitor tRNA was used). Bound RNA was partitioned by nitrocellulose filtration and quantitated. Data were analyzed as described in
15 the Materials and Methods.

Figure 6 shows specificity of the bioactivity of lead TGF β 1 and TGF β 2 aptamers and comparison with commercial antibody preparations. RNA was either synthesized by phosphoramidite chemistry (NX22283) or by *in vitro* transcription. Indicator cells (mink lung epithelial cells) were incubated with either TGF β 1, TGF β 2 or TGF β 3 and dilutions of RNA or
20 antibody as described. The extent of cell proliferation was measured by 3 H-thymidine incorporation and the data were analyzed as described. The points represent an average of n=2-6 and error bars are standard errors. Symbols designated by TGF β 1, TGF β 2 or TGF β 3 indicate data obtained from cells treated with either TGF β 1, TGF β 2 or TGF β 3, respectively. MAB and pAB designate monoclonal and polyclonal antibodies, respectively. Random, NX22283 and 40-
25 03 designate the use of random RNA, the TGF β 2 or the TGF β 1 lead aptamer, respectively. The aptamer 40-03 was described in the TGF β 1 patent (U.S. Patent No. 6,124,449, entitled "High-Affinity TGF β Nucleic Acid Ligands and Inhibitors").

Figure 7 shows boundaries of TGF β 2 ligands 14-1, 21-21 and 21-4. RNA aptamers were end labeled at the 5' end (3'B) or at the 3' end (5'B), partially hydrolyzed at high pH, and
30 partitioned for binding to TGF β 2 by nitrocellulose filtration as described in the Materials and

Methods. The amounts of TGF β 2 used for binding partitioning is as shown. Recovered RNA was analyzed on high resolution sequencing gels and visualized by autoradiography. Unselected hydrolyzed RNA was used as a marker (Alk. hydr.) to align the banding pattern to the sequence of each ligand. The observed boundary bands are shown with (*) and their position in the sequence pattern is shown by arrowheads. No protein and input lanes show the background binding to nitrocellulose and the starting unhydrolyzed RNA. The observed boundaries for each ligand is summarized at the bottom of the figure.

5 **Figure 8** shows the putative structures of TGF β 2 aptamers. The minimal required sequences were fit into similar structures. Ligand 14i-1t5-41 and 21a-4(ML-110) were transcribed *in vitro* and contained extra bases at their 5' ends (shown in lower case) to allow 10 efficient *in vitro* transcription. Bold-faced letters indicate positions that are identical to invariant positions of the biased SELEX with the 21-21 sequence.

15 **Figure 9** shows the molecular description of NX22323 40k PEG. rG = 2'-OH G; rA = 2'-OH A; FU = 2'-FU; FC = 2'-FC.

15 **Figure 10** shows the putative structure of lead truncate ligand CD70. Lower case letters indicate positions requiring 2'-OH. • indicates GU base pairing.

Figure 11 shows the pharmacokinetics of TGF β aptamer in sprague dawley rats.

DETAILED DESCRIPTION OF THE INVENTION

20 This application describes high-affinity nucleic acid ligands to TGF β 2 identified through the method known as SELEX. SELEX is described in U.S. Patent Application Serial No. 07/536,428, entitled "Systematic Evolution of Ligands by EXponential Enrichment," now abandoned, U.S. Patent Application Serial No. 07/714,131, filed June 10, 1991, entitled "Nucleic Acid Ligands," now U.S. Patent No. 5,475,096 and U.S. Patent Application Serial No. 25 07/931,473, filed August 17, 1992, entitled "Methods for Identifying Nucleic Acid Ligands," now U.S. Patent No. 5,270,163 (see also WO91/19813). These applications, each specifically incorporated herein by reference, are collectively called the SELEX Patent Applications. Nucleic Acid Ligands to TGF β have been identified through the SELEX method. These TGF β Nucleic Acid Ligands are described in U. S. Patent Application Serial No. 08/458,423, filed June 2, 1995, 30 entitled, "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No.

5,731,144 and U.S. Patent Application Serial No. 09/046,247, filed March 23, 1998, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," and U.S. Patent Application Serial No. 09/275,850, filed March 24, 1999, entitled "Truncation SELEX Method." These applications are specifically incorporated herein in their entirety.

5 Certain terms used to described the invention herein are defined as follows:

"Nucleic Acid Ligand" as used herein is a non-naturally occurring nucleic acid having a desirable action on a target. Nucleic Acid Ligands are also referred to herein as "aptamers." A desirable action includes, but is not limited to, binding of the target, catalytically changing the target, reacting with the target in a way which modifies/alters the target or the functional activity 10 of the target, covalently attaching to the target as in a suicide inhibitor, and facilitating the reaction between the target and another molecule. In the preferred embodiment, the desirable action is specific binding to a target molecule, such target molecule being a three dimensional chemical structure other than a polynucleotide that binds to the nucleic acid ligand through a mechanism which predominantly depends on Watson/Crick base pairing or triple helix binding, 15 wherein the nucleic acid ligand is not a nucleic acid having the known physiological function of being bound by the target molecule. Nucleic acid ligands include nucleic acids that are identified from a candidate mixture of nucleic acids, said nucleic acid ligand being a ligand of a given target by the method comprising: a) contacting the candidate mixture with the target, wherein nucleic acids having an increased affinity to the target relative to the candidate mixture may be 20 partitioned from the remainder of the candidate mixture; b) partitioning the increased affinity nucleic acids from the remainder of the candidate mixture; and c) amplifying the increased affinity nucleic acids to yield a ligand-enriched mixture of nucleic acids.

"Candidate Mixture" is a mixture of nucleic acids of differing sequence from which to select a desired ligand. The source of a candidate mixture can be from naturally-occurring 25 nucleic acids or fragments thereof, chemically synthesized nucleic acids, enzymatically synthesized nucleic acids or nucleic acids made by a combination of the foregoing techniques. In a preferred embodiment, each nucleic acid has fixed sequences surrounding a randomized region to facilitate the amplification process.

"Nucleic Acid" means either DNA, RNA, single-stranded or double-stranded and any 30 chemical modifications thereof. Modifications include, but are not limited to, those which

provide other chemical groups that incorporate additional charge, polarizability, hydrogen bonding, electrostatic interaction, and fluxionality to the nucleic acid ligand bases or to the nucleic acid ligand as a whole. Such modifications include, but are not limited to, 2'-position sugar modifications, 5-position pyrimidine modifications, 8-position purine modifications, 5 modifications at exocyclic amines, substitution of 4-thiouridine, substitution of 5-bromo or 5- iodo-uracil, backbone modifications, methylations, unusual base-pairing combinations such as the isobases isocytidine and isoguanidine and the like. Modifications can also include 3' and 5' modifications such as capping.

"SELEX" methodology involves the combination of selection of nucleic acid ligands 10 which interact with a target in a desirable manner, for example binding to a protein, with amplification of those selected nucleic acids. Iterative cycling of the selection/amplification steps allows selection of one or a small number of nucleic acids which interact most strongly with the target from a pool which contains a very large number of nucleic acids. Cycling of the selection/amplification procedure is continued until a selected goal is achieved. In the present 15 invention, the SELEX methodology is employed to obtain nucleic acid ligands to TGF β 2. The SELEX methodology is described in the SELEX Patent Applications.

"Target" means any compound or molecule of interest for which a ligand is desired. A target can be a protein, peptide, carbohydrate, polysaccharide, glycoprotein, hormone, receptor, antigen, antibody, virus, substrate, metabolite, transition state analog, cofactor, inhibitor, drug, 20 dye, nutrient, growth factor, etc. without limitation. In this application, the target is TGF β 2.

In its most basic form, the SELEX process may be defined by the following series of steps:

1) A candidate mixture of nucleic acids of differing sequence is prepared. The candidate mixture generally includes regions of fixed sequences (i.e., each of the members of the candidate 25 mixture contains the same sequences in the same location) and regions of randomized sequences. The fixed sequence regions are selected either: (a) to assist in the amplification steps described below, (b) to mimic a sequence known to bind to the target, or (c) to enhance the concentration of a given structural arrangement of the nucleic acids in the candidate mixture. The randomized sequences can be totally randomized (i.e., the probability of finding a base at any position being 30 one in four) or only partially randomized (e.g., the probability of finding a base at any location

can be selected at any level between 0 and 100 percent).

2) The candidate mixture is contacted with the selected target under conditions favorable for binding between the target and members of the candidate mixture. Under these circumstances, the interaction between the target and the nucleic acids of the candidate mixture 5 can be considered as forming nucleic acid-target pairs between the target and those nucleic acids having the strongest affinity for the target.

3) The nucleic acids with the highest affinity for the target are partitioned from those nucleic acids with lesser affinity to the target. Because only an extremely small number of sequences (and possibly only one molecule of nucleic acid) corresponding to the highest affinity 10 nucleic acids exist in the candidate mixture, it is generally desirable to set the partitioning criteria so that a significant amount of the nucleic acids in the candidate mixture (approximately 5-50%) are retained during partitioning.

4) Those nucleic acids selected during partitioning as having the relatively higher affinity to the target are then amplified to create a new candidate mixture that is enriched in nucleic acids 15 having a relatively higher affinity for the target.

5) By repeating the partitioning and amplifying steps above, the newly formed candidate mixture contains fewer and fewer weakly binding sequences, and the average degree of affinity of the nucleic acids to the target will generally increase. Taken to its extreme, the SELEX process will yield a candidate mixture containing one or a small number of unique nucleic acids 20 representing those nucleic acids from the original candidate mixture having the highest affinity to the target molecule.

The SELEX Patent Applications describe and elaborate on this process in great detail. Included are targets that can be used in the process; methods for partitioning nucleic acids within a candidate mixture; and methods for amplifying partitioned nucleic acids to generate enriched 25 candidate mixture. The SELEX Patent Applications also describe ligands obtained to a number of target species, including both protein targets where the protein is and is not a nucleic acid binding protein.

The SELEX method further encompasses combining selected nucleic acid ligands with lipophilic or non-immunogenic, high molecular weight compounds in a diagnostic or therapeutic 30 complex as described in U.S. Patent Application No. 08/434,465, filed May 4, 1995, entitled

"Nucleic Acid Ligand Complexes," now U.S. Patent No. 6,011,020. VEGF nucleic acid ligands that are associated with a Lipophilic Compound, such as diacyl glycerol or dialkyl glycerol, in a diagnostic or therapeutic complex are described in U.S. Patent Application Serial No. 08/739,109, filed October 25, 1996, entitled "Vascular Endothelial Growth Factor (VEGF) Nucleic Acid Ligand

5 Complexes," now U.S. Patent No. 5,859,228. VEGF nucleic acid ligands that are associated with a Lipophilic Compound, such as a glycerol lipid, or a non-immunogenic, high molecular weight Compound, such as polyalkylene glycol, are further described in U.S. Patent Application Serial No. 08/897,351, filed July 21, 1997, entitled "Vascular Endothelial Growth Factor (VEGF) Nucleic Acid Ligand Complexes," now U.S. Patent No. 6,051,698. VEGF nucleic acid ligands that are 10 associated with a non-immunogenic, high molecular weight compound or lipophilic compound are also further described in PCT/US 97/18944 (WO98/18480), filed October 17, 1997, entitled "Vascular Endothelial Growth Factor (VEGF) Nucleic Acid Ligand Complexes". Each of the above described patent applications which describe modifications of the basic SELEX procedure are specifically incorporated by reference herein in their entirety.

15 In certain embodiments of the present invention it is desirable to provide a complex comprising one or more nucleic acid ligands to TGF β 2 covalently linked with a non-immunogenic, high molecular weight compound or lipophilic compound. A complex as used herein describes the molecular entity formed by the covalent linking of the nucleic acid ligand of TGF β 2 to a non-immunogenic, high molecular weight compound. A non-immunogenic, high molecular weight 20 compound is a compound between approximately 100 Da to 1,000,000 Da, more preferably approximately 1000 Da to 500,000 Da, and most preferably approximately 1000 Da to 200,000 Da, that typically does not generate an immunogenic response. For the purposes of this invention, an immunogenic response is one that causes the organism to make antibody proteins. In one preferred embodiment of the invention, the non-immunogenic, high molecular weight compound is a 25 polyalkylene glycol. In the most preferred embodiment, the polyalkylene glycol is polyethylene glycol (PEG). More preferably, the PEG has a molecular weight of about 10-80K. Most preferably, the PEG has a molecular weight of about 20-45K. In certain embodiments of the invention, the non-immunogenic, high molecular weight compound can also be a nucleic acid ligand.

In another embodiment of the invention it is desirable to have a complex comprised of a nucleic acid ligand to TGF β 2 and a lipophilic compound. Lipophilic compounds are compounds that have the propensity to associate with or partition into lipid and/or other materials or phases with low dielectric constants, including structures that are comprised substantially of lipophilic components. Lipophilic compounds include lipids as well as non-lipid containing compounds that have the propensity to associate with lipid (and/or other materials or phases with low dielectric constants). Cholesterol, phospholipid, and glycerol lipids, such as dialkylglycerol, diacylglycerol, and glycerol amide lipids are further examples of lipophilic compounds. In a preferred embodiment, the lipophilic compound is a glycerol lipid.

The non-immunogenic, high molecular weight compound or lipophilic compound may be covalently bound to a variety of positions on the nucleic acid ligand to TGF β 2, such as to an exocyclic amino group on the base, the 5-position of a pyrimidine nucleotide, the 8-position of a purine nucleotide, the hydroxyl group of the phosphate, or a hydroxyl group or other group at the 5' or 3' terminus of the nucleic acid ligand to TGF β 2. In embodiments where the lipophilic compound is a glycerol lipid, or the non-immunogenic, high molecular weight compound is polyalkylene glycol or polyethylene glycol, preferably the non-immunogenic, high molecular weight compound is bonded to the 5' or 3' hydroxyl of the phosphate group thereof. In the most preferred embodiment, the lipophilic compound or non-immunogenic, high molecular weight compound is bonded to the 5' hydroxyl of the phosphate group of the nucleic acid ligand.

Attachment of the non-immunogenic, high molecular weight compound or lipophilic compound to the nucleic acid ligand of TGF β can be done directly or with the utilization of linkers or spacers.

A "linker" is a molecular entity that connects two or more molecular entities through covalent bonds or non-covalent interactions, and can allow spatial separation of the molecular entities in a manner that preserves the functional properties of one or more of the molecular entities.

A linker can also be known as a "spacer."

The complex comprising a nucleic acid ligand to TGF β 2 and a non-immunogenic, high molecular weight compound or lipophilic compound can be further associated with a lipid construct. Lipid constructs are structures containing lipids, phospholipids, or derivatives thereof comprising a variety of different structural arrangements which lipids are known to adopt in aqueous suspension. These structures include, but are not limited to, lipid bilayer vesicles,

micelles, liposomes, emulsions, lipid ribbons or sheets, and may be complexed with a variety of drugs and components which are known to be pharmaceutically acceptable. In the preferred embodiment, the lipid construct is a liposome. The preferred liposome is unilamellar and has a relative size less than 200 nm. Common additional components in lipid constructs include

5 cholesterol and alpha-tocopherol, among others. The lipid constructs may be used alone or in any combination which one skilled in the art would appreciate to provide the characteristics desired for a particular application. In addition, the technical aspects of lipid constructs and liposome formation are well known in the art and any of the methods commonly practiced in the field may be used for the present invention.

10 The SELEX method further comprises identifying bioconjugates to a target. Copending PCT Patent Application No. PCT/US98/00589 (WO 98/18480), filed January 7, 1998, entitled "Bioconjugation of Oligonucleotides" describes a method for enzymatically synthesizing bioconjugates comprising RNA derivatized exclusively at the 5'-position with a molecular entity, and a method for identifying bioconjugates to a target comprising nucleic acid ligands

15 derivatized with a molecular entity exclusively at the 5'-position of the nucleic acid ligands. A bioconjugate as used herein refers to any oligonucleotide which has been derivatized with another molecular entity. In the preferred embodiment, the molecular entity is a macromolecule.

As used herein, a macromolecule refers to a large organic molecule. Examples of macromolecules include, but are not limited to nucleic acids, oligonucleotides, proteins, peptides,

20 carbohydrates, polysaccharides, glycoproteins, lipophilic compounds, such as cholesterol, phospholipids, diacyl glycerols and dialkyl glycerols, hormones, drugs, non-immunogenic high molecular weight compounds, fluorescent, chemiluminescent and bioluminescent marker compounds, antibodies and biotin, etc. without limitation. In certain embodiments, the molecular entity may provide certain desirable characteristics to the nucleic acid ligand, such as increasing

25 RNA hydrophobicity and enhancing binding, membrane partitioning and/or permeability. Additionally, reporter molecules, such as biotin, fluorescein or peptidyl metal chelates for incorporation of diagnostic radionuclides may be added, thus providing a bioconjugate which may be used as a diagnostic agent.

The methods described herein and the nucleic acid ligands identified by such methods are
30 useful for both therapeutic and diagnostic purposes. Therapeutic uses include the treatment or

prevention of diseases or medical conditions in human patients. Therapeutic uses may also include veterinary applications.

Diagnostic utilization may include both *in vivo* or *in vitro* diagnostic applications. The SELEX method generally, and the specific adaptations of the SELEX method taught and claimed 5 herein specifically, are particularly suited for diagnostic applications. SELEX identifies nucleic acid ligands that are able to bind targets with high affinity and with surprising specificity. These characteristics are, of course, the desired properties one skilled in the art would seek in a diagnostic ligand.

The nucleic acid ligands of the present invention may be routinely adapted for diagnostic 10 purposes according to any number of techniques employed by those skilled in the art or by the methods described in PCT/US98/00589 (WO 98/18480). Diagnostic agents need only be able to allow the user to identify the presence of a given target at a particular locale or concentration. Simply the ability to form binding pairs with the target may be sufficient to trigger a positive 15 signal for diagnostic purposes. Those skilled in the art would also be able to adapt any nucleic acid ligand by procedures known in the art to incorporate a labeling tag in order to track the presence of such ligand. Such a tag could be used in a number of diagnostic procedures. The nucleic acid ligands to TGF β 2 described herein may specifically be used for identification of the TGF β 2 protein.

SELEX provides high affinity ligands of a target molecule. This represents a singular 20 achievement that is unprecedented in the field of nucleic acids research. The present invention applies the SELEX procedure to the specific target of TGF β 1. In the Example section below, the experimental parameters used to isolate and identify the nucleic acid ligands to TGF β 2 are described.

In order to produce nucleic acids desirable for use as a pharmaceutical, it is preferred that 25 the nucleic acid ligand (1) binds to the target in a manner capable of achieving the desired effect on the target; (2) be as small as possible to obtain the desired effect; (3) be as stable as possible; and (4) be a specific ligand to the chosen target. In most situations, it is preferred that the nucleic acid ligand have the highest possible affinity to the target.

In co-pending and commonly assigned U.S. Patent Application Serial No. 07/964,624, 30 filed October 21, 1992 ('624), methods are described for obtaining improved nucleic acid ligands

after SELEX has been performed. The '624 application, entitled "Nucleic Acid Ligands to HIV-RT and HIV-1 Rev," now issued as U.S. Patent No. 5,496,938, is specifically incorporated herein by reference.

In the present invention, SELEX experiments were performed in order to identify RNA ligands with specific high affinity for TGF β 2 from degenerate libraries containing 33, 34 or 40 random positions (33N, 34N or 40N) (**Table 1**). This invention includes the specific RNA ligands to TGF β 2 shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193), identified by the methods described in Example 1. This invention further includes RNA ligands to TGF β 2 which inhibit TGF β 2 function, presumably by inhibiting the interaction of TGF β 2 with its receptor. The scope of the ligands covered by this invention extends to all nucleic acid ligands of TGF β 2, modified and unmodified, identified according to the SELEX procedure. More specifically, this invention includes nucleic acid sequences that are substantially homologous to the ligands shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193). By substantially homologous it is meant a degree of primary sequence homology in excess of 70%, most preferably in excess of 80%, and even more preferably in excess of 90%, 95% or 99%. The percentage of homology as described herein is calculated as the percentage of nucleotides found in the smaller of the two sequences which align with identical nucleotide residues in the sequence being compared when 1 gap in a length of 10 nucleotides may be introduced to assist in that alignment. A review of the sequence homologies of the ligands of TGF β 2, shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193) shows that some sequences with little or no primary homology may have substantially the same ability to bind TGF β 2. For these reasons, this invention also includes nucleic acid ligands that have substantially the same structure and ability to bind TGF β 2 as the nucleic acid ligands shown in **Tables 5, 7, 8, 11, 13, 14, 16-19** and **Figure 9** (SEQ ID NOS:21-121 and 128-193). Substantially the same ability to bind TGF β 2 means that the affinity is within one or two orders of magnitude of the affinity of the ligands described herein. It is well within the skill of those of ordinary skill in the art to determine whether a given sequence -- substantially homologous to those specifically described herein -- has substantially the same ability to bind TGF β .

30 This invention also includes nucleic acid ligands that have substantially the same

postulated structure or structural motifs. Substantially the same structure or structural motifs can be postulated by sequence alignment using the Zukerfold program (see Zuker (1989) *Science* 244:48-52). As would be known in the art, other computer programs can be used for predicting secondary structure and structural motifs. Substantially the same structure or structural motif of 5 nucleic acid ligands in solution or as a bound structure can also be postulated using NMR or other techniques as would be known in the art.

One potential problem encountered in the therapeutic, prophylactic, and *in vivo* diagnostic use of nucleic acids is that oligonucleotides in their phosphodiester form may be quickly degraded in body fluids by intracellular and extracellular enzymes such as endonucleases and 10 exonucleases before the desired effect is manifest. Certain chemical modifications of the nucleic acid ligand can be made to increase the *in vivo* stability of the nucleic acid ligand or to enhance or to mediate the delivery of the nucleic acid ligand. See, e.g., U.S. Patent Application Serial No. 08/117,991, filed September 8, 1993, entitled "High Affinity Nucleic Acid Ligands Containing Modified Nucleotides," now abandoned and U.S. Patent Application Serial No. 08/434,465, filed 15 May 4, 1995, entitled "Nucleic Acid Ligand Complexes," now U.S. Patent No. 6,011,020, which are specifically incorporated herein by reference. Modifications of the nucleic acid ligands contemplated in this invention include, but are not limited to, those which provide other chemical groups that incorporate additional charge, polarizability, hydrophobicity, hydrogen bonding, electrostatic interaction, and fluxionality to the nucleic acid ligand bases or to the nucleic acid 20 ligand as a whole. Such modifications include, but are not limited to, 2'-position sugar modifications, 5-position pyrimidine modifications, 8-position purine modifications, modifications at exocyclic amines, substitution of 4-thiouridine, substitution of 5-bromo or 5-iodo-uracil, backbone modifications, phosphorothioate or alkyl phosphate modifications, methylations, unusual base-pairing combinations such as the isobases isocytidine and 25 isoguanidine and the like. Modifications can also include 3' and 5' modifications such as capping.

Where the nucleic acid ligands are derived by the SELEX method, the modifications can be pre- or post- SELEX modifications. Pre-SELEX modifications yield nucleic acid ligands with both specificity for their SELEX Target and improved *in vivo* stability. Post-SELEX 30 modifications made to 2'-OH nucleic acid ligands can result in improved *in vivo* stability without

adversely affecting the binding capacity of the nucleic acid ligand. The preferred modifications of the nucleic acid ligands of the subject invention are 5' and 3' phosphorothioate capping and/or 3'-3' inverted phosphodiester linkage at the 3' end. In one preferred embodiment, the preferred modification of the nucleic acid ligand is a 3'-3' inverted phosphodiester linkage at the 3' end.

5 Additional 2'-fluoro (2'-F) and/or 2'-amino (2'-NH₂) and/or 2'-O methyl (2'-OMe) and/or 2'-OCH₃ modification of some or all of the nucleotides is preferred. Described herein are nucleic acid ligands that were 2'-F modified and incorporated into the SELEX process. Also described herein are nucleic acid ligands that were 2'-OCH₃ modified after the SELEX process was performed.

10 Other modifications are known to one of ordinary skill in the art. Such modifications may be made post-SELEX (modification of previously identified unmodified ligands) or by incorporation into the SELEX process.

15 As described above, because of their ability to selectively bind TGF β 2, the nucleic acid ligands to TGF β 2 described herein are useful as pharmaceuticals. This invention, therefore, also includes a method for treating TGF β 2-mediated pathological conditions by administration of a nucleic acid ligand capable of binding to TGF β 2.

Therapeutic compositions of the nucleic acid ligands may be administered parenterally by injection, although other effective administration forms, such as intraarticular injection, inhalant mists, orally active formulations, transdermal iontophoresis or suppositories, are also envisioned.

20 One preferred carrier is physiological saline solution, but it is contemplated that other pharmaceutically acceptable carriers may also be used. In one preferred embodiment, it is envisioned that the carrier and the ligand constitute a physiologically-compatible, slow release formulation. The primary solvent in such a carrier may be either aqueous or non-aqueous in nature. In addition, the carrier may contain other pharmacologically-acceptable excipients for modifying or maintaining the pH, osmolarity, viscosity, clarity, color, sterility, stability, rate of dissolution, or odor of the formulation. Similarly, the carrier may contain still other pharmacologically-acceptable excipients for modifying or maintaining the stability, rate of dissolution, release, or absorption of the ligand. Such excipients are those substances usually and customarily employed to formulate dosages for parental administration in either unit dose or multi-dose form.

30 Once the therapeutic composition has been formulated, it may be stored in sterile vials as

a solution, suspension, gel, emulsion, solid, or dehydrated or lyophilized powder. Such formulations may be stored either in a ready to use form or requiring reconstitution immediately prior to administration. The manner of administering formulations containing nucleic acid ligands for systemic delivery may be via subcutaneous, intramuscular, intravenous, intranasal or 5 vaginal or rectal suppository.

The following Examples are provided to explain and illustrate the present invention and are not intended to be limiting of the invention. Example 1 describes the various materials and experimental procedures used in Examples 2-5. Example 2 describes the isolation and characteristics of Nucleic Acid Ligands that bind human TGF β 2. Example 3 describes the 10 Nucleic Acid Ligands isolated by the SELEX method using a biased round O library, the sequences of TGF β 2 Nucleic Acid Ligands isolated from the biased SELEX process, and the binding of Nucleic Acid Ligands isolated from the biased SELEX process. Example 4 describes substitutions of 2'-OH purines with 2'OCH₃ purines in NX22284 and NX222385. Example 5 describes the pharmacokinetic properties of NX22323. Example 6 describes 2'-OMe 15 modification of lead TGF β 1 truncate ligand CD70.

EXAMPLES

EXAMPLE 1. Experimental Procedures

Materials and Methods

20 Monoclonal and polyclonal antibodies that recognize human TGF β 1, TGF β 2 or TGF β 3 were purchased from R&D Systems, Inc. (Minneapolis, MN). DNA oligonucleotides were purchased from Operon, Inc. (Alameda, CA) or Oligos, Etc. (Redding Center, CT). The BIACore 2000 and IAsys *plus* instruments are products of Biacore, Inc. (Paramus, NJ) and Affinity Sensors, Inc. (Cambridge, U. K.), respectively. Nitrocellulose filters and filtering manifolds were 25 obtained from Millipore (Bedford, MA). Mink lung epithelial cells (#CCL64) were purchased from the American Type Culture Collection (Rockville, MD). The cloning vectors pCR-Script and pUC9 were obtained in-house or from Stratagene, Inc. (La Jolla, CA) or Life Technologies, Inc. (Gaithersburg, MD), respectively. *E coli* strains were obtained from Stratagene. The QIAprep spin miniprep kit was from QIAgen, Inc. (Chatsworth, CA). The Big Dye sequencing 30 kit and model 377 sequencer can be purchased from Applied Biosystems (Foster City, CA). T7

RNA polymerase and *Thermus aquaticus* DNA polymerase were purchased from Enzyco, Inc. (Denver, CO) and Perkin Elmer (Norwalk, CT), respectively. All restriction enzymes were purchased from New England Biolabs. *E. coli* RNase H was obtained from Boehringer Mannheim. All synthetic nucleic acids with a name that begins with "NX" were synthesized at 5 NeXstar Pharmaceuticals, Inc. (Boulder, CO) using an ABI model 394 DNA/RNA synthesizer (Applied Biosystems). Yeast tRNA (type X-SA) and porcine intestinal mucosca-derived heparin (molecular weight 5000), were purchased from Sigma (St. Louis, MO) and Calbiochem (La Jolla, CA), respectively.

10 Preparation of round 0 nucleic acid library

The initial (round 0) library of ribonucleic acid molecules that was used to isolate TGF β 2 nucleic acid ligands was generated as follows. Two DNA oligonucleotides (**40 N7 round 0 DNA template and 5'N7 primer**) were annealed and filled in with Klenow to produce a **40 N7 round 0 DNA transcription template (Table 1)**. This template was transcribed using T7 RNA 15 polymerase, 3 mM 2'-fluoro uridine and cytosine, 1 mM 2'-hydroxyl guanosine and adenine, and α 32 P-ATP as described in (Fitzwater and Polisky (1996) Meth. Enz. 267:275-301). This resulted in a **round 0 40N7 nucleic acid** pool with the following sequence which has 5' and 3' "fixed" regions and a 40 base long random sequence region:

5'-GGGAGGACGAUGCGG-40N-CAGACGACUCGCCGA-3' **round 0 40N7 nucleic acid**
20 5' fixed region random region 3' fixed region (SEQ ID NO:6)

A=2'-OH A; C=2'-F C; G=2'-OH G; U=2'-F U (Table 1)

Spot SELEX

25 Spot SELEX was performed as described in U.S. Patent Application No. 08/477,527, filed June 7, 1995, entitled "High Affinity Nucleic Acid Ligands of Cytokines," now U.S. Patent No. 5,972,599, which is hereby incorporated by reference in its entirety, using nucleic acid that was internally labeled using α - 32 P ATP. The conditions and progress of this SELEX experiment are summarized in **Table 3**. Briefly, human TGF β 2 (or no protein) was applied to a 13 mm 30 diameter nitrocellulose filter and allowed to absorb but not completely dry. The filter was

incubated with RNA in Dulbecco's phosphate-buffered saline, 1 mM MgCl₂ and then washed as summarized in **Table 3**. Filter-bound and protein-bound nucleic acid was visualized and quantitated on an Instant *Imager* (Packard Instrument Co., Downers Grove, IL) and the protein-bound nucleic acid was eluted in 50% phenol, 4 M urea for 45 minutes at 65°C. Eluted nucleic acid was ethanol precipitated and then reverse transcribed using avian myeloblastosis virus reverse transcriptase and subjected to the polymerase chain reaction using 5'N7 and 3'N7 primers for 15 cycles. This resulting transcription template was transcribed with T7 RNA polymerase in the presence of 2'-fluoro pyrimidine nucleotides, 2'-OH purine ribonucleotides, and α -³²P-ATP, and carried to the next spot round. The pool from the first spot round was also transcribed as above in the absence of α -³²P-ATP for use in round 2 of the surface plasmon resonance biosensor SELEX.

Surface plasmon resonance biosensor SELEX

Rounds 2-spr through 9-spr were done using surface plasmon resonance biosensor technology on a BIACore model 2000 instrument. For this experiment 1XDPBS, 1 mM MgCl₂, 0.005% P20 surfactant (cat#BR-1000-54, Biacore, Inc., Piscataway, NJ) was used as the running buffer. TGF β 2 was amine coupled onto a CM5 BIACORE chip (Biacore, Inc., Piscataway, NJ) using the Biacore amine coupling kit (cat#BR-1000-50, Biacore, Inc., Piscataway, NJ) per manufacturer's instructions. Briefly, TGF β 2 aliquots (3 μ l, in 4 mM HCl at 100 μ g/ml) were diluted in 30 μ l of 10 mM CH₃COONa, pH 5.0 and injected on an EDC-NHS activated chip at 25°C, 5 μ l/min, in different volumes to achieve different loading levels, as measured in response units (RU). Following coupling, the chip was washed with 3 M NaCl for about 1.5 min at 10 μ l/min. Under these experimental conditions, TGF β 2 loading of 15 RU/ μ l could be achieved. TGF β 2 was loaded in flow cells 1, 2, and 3, while flow cell 4 was kept blank for control and background subtractions. Before use, the chip was tested for activity by testing binding of LAP and or soluble receptor III (R&D Systems, Minneapolis, MN) at 37°C. At the end of each test injections the chip was regenerated using 1 min wash with 10 mM NaOH. For SELEX rounds, RNA pools, generated by *in vitro* transcription without any labeled nucleotides, were in running buffer and were injected over the TGF β 2 loaded CM5 chips at 5 μ l/min at 37°C. The concentration and volume of the RNA pools used at each round are as shown in **Table 4**. At

each round the RNA pools were applied in 40 μ l injections and each injection cycle was followed by a dissociation phase where the chip was washed with DPBS, 1 mM MgCl₂ at 20 μ l/min while three 100 μ l fractions (5 min each) were collected. Following the last injection-dissociation cycle, the chip was treated with 0.25% SDS and the eluted RNA was collected as the final 5 fraction. The third fractions of each injection cycle and the SDS elution were pooled and amplified by RT/PCR to generate the template pool for the next SELEX round.

10 Resonant Mirror Optical Biosensor SELEX

Rounds 10-rm through 13-rm were done using an IASYS *plus* resonant mirror optical biosensor instrument. Round 9-spr from the surface plasmon resonance SELEX was used as the starting material. For this experiment, 1XDPBS, 1 mM MgCl₂, 0.005% P20 surfactant (cat#BR-1000-54, Biacore, Inc., Piscataway, NJ) were used as the running buffer. TGF β 2 was amine 15 coupled onto a CMD IASYS cuvette (Affinity Sensors, Cambridge, UK) according to the manufacturer's protocol. Briefly, the CMD cuvette was activated with 0.2 M EDC, 0.05 M NHS for 10 minutes, and TGF β 2 was coupled by injection 35 μ l of 0.4 μ M TGF β 2, 10 mM CH₃COONa, pH 5.5 in 35 μ l of 10 mM CH₃COONa, pH 5.5. The coupling reaction was at 25°C for about 10 minutes and resulted in about 2,000 Arcsec of signal. Unreacted sites were capped 20 by exposing the cuvette in 1 M ethanolamine for 1-2 minutes. Following coupling and capping the cuvette was exposed to 3 M NaCl for 1-2 minutes and was ready for use. The cuvettes were routinely tested for activity by measuring binding of LAP and or soluble receptor III (R&D Systems, Minneapolis, MN) at 37°C. At the end of each test injection the chip was regenerated using a 1 minute wash with 50 mM NaCO₃. For SELEX rounds, RNA pools, generated by *in* 25 *vitro* transcription without any labeled nucleotides, were in running buffer. They were injected in the TGF β 2 loaded CMD cuvette and incubated for 27-60 minutes (**Table 6**) under 100% steering at 37°C. Following binding, the RNA was replaced with buffer and bound RNA was observed to dissociate from the cuvette surface. Dissociation was allowed for 30-150 minutes (**Table 6**) at 37°C while the buffer was exchanged several times to avoid evaporation. Following

dissociation, the remaining RNA was eluted with H₂O or 0.25% SDS and the RNA was amplified as above and carried to the next SELEX round.

SELEX using filter partitioning and polyanion competition

5 For rounds 9b through 22a, SELEX using filter partitioning was performed essentially as described in (Fitzwater and Polisky (1996) *Meth. Enz.* 267:275-301) except that 1) heparin or yeast tRNA was included to compete off ligands that bound nonspecifically, 2) the binding buffer was HBSMCK (50 mM HEPES, pH 7.4, 140 mM NaCl, 1 mM MgCl₂, 1 mM CaCl₂, 3 mM KCl), 3) extensive efforts were undertaken to reduce filter binding sequences (preadsorption of 10 nucleic acid onto filters after elution and transcription, blocking of filters with tRNA and bovine serum albumin prior to partitioning, addition of 0.5 M urea to the wash buffer) and 4) the transcripts were initiated with a 5:1 molar mixture of guanosine:2'-fluoro-nucleotides. Initiation with guanosine allows nucleic acids to be used in SELEX or bioactivity assays without radiolabeling and alleviates a phosphatase step if the nucleic acid is to be 5'-end radiolabeled for 15 binding studies.

Round 8-spr from the surface plasmon resonance SELEX was used as the starting material. From rounds 9b to 14i, the SELEX process was performed using protein-excess conditions. The concentrations of nucleic acid and protein were equimolar in round 15c. Nucleic acid-excess conditions were used from rounds 16a to 22a (**Table 2**). Competitors (yeast 20 tRNA and heparin) were used from rounds 9b to 14i. Filters were washed with 10-15 ml HBSMCK buffer from rounds 9b to 12d and increasing amounts (5-50 ml) of HBSMCK, 0.5 M urea from rounds 13i to 22a.

Sequencing of nucleic acid ligand pools

25 Nucleic acid pools were sequenced as described in (Fitzwater and Polisky (1996) *Meth. Enz.* 267:275-301).

Screening nucleic acid ligand pools using ligand-specific reverse transcription-polymerase chain reactions

Nucleic acids from the various pools was reverse transcribed with clone-^{"specific"} primers (ML-85 for ligand 14i-1 and ML-81 for ligand 21a-21) for 12, 15 or 18 cycles. Mixtures of pure nucleic acid ligands and round 0 40N7 nucleic acid that contained 10%, 3%, 1%, 0.3%, or 0.1% ligand were processed in the same manner and served to quantitate signals 5 from RT-PCR of the nucleic acid pools.

Cloning, screening and sequencing of nucleic acid ligands

Nucleic acid ligands were cloned using two methods. In one method the ligands were directly cloned into pCR-Script according to the manufacturer's instructions and transformed into 10 *E. coli* strain XL-1 Blue MRF' Kan. In the other method the double-stranded DNA transcription template was amplified by PCR using primers **ML-34** and **ML-78**, digested with BamHI and EcoRI restriction enzymes, and cloned into BamHI and EcoRI-digested pUC9. The ligation was transformed into *E. coli* strain DH5 α . Colonies were selected on ampicillin plates and screened for inserts by PCR using vector-specific primers (**RSP and FSP2**). Typically 90%-100% of the 15 clones had inserts. Some colonies or nucleic acid pools were also screened using 14i-1, 21a-4 or 21a-21 ligand-specific primers (ML-79, ML-81 and ML-85, respectively) in an attempt to identify clones that were different from those already isolated.

Plasmid minipreps from the transformants were prepared using the QIAprep spin 20 miniprep kit (QIAGEN, Inc., Valencia, CA) or PERFECT prep plasmid DNA kit (5'3', Inc., Boulder, CO). Sequencing reactions were performed with the Big Dye kit and a sequencing primer (**RSP2**). The sequencing products were analyzed on an ABI model 377 sequencer.

Nucleic acid ligand boundaries

The boundaries (5' and 3' end) of the smallest ligand that can bind TGF β 2 was 25 determined essentially as described in (Fitzwater and Polisky (1996) Meth. Enz. 267:275-301). The protein concentrations used were 0, 1 nM, and 10 nM and the nucleic acid /protein ratio was 1. The binding buffer used in this experiment was HBSMC, 0.01% HSA. Binding reactions were incubated at 37°C for 30 minutes, filtered through 0.45 μ m, nitrocellulose filters (15 30 mm), and then washed with 15 ml HBSMC. The RNA was recovered by phenol-urea extraction, eluted RNA was ethanol precipitated in the presence of glycogen, resuspended in H₂O,

supplemented with equal volume 2X formamide dye, and analyzed on 8% acrylamide, 8 M urea sequencing gels. Truncated RNAs that were bound to TGF β 2 were visualized and developed on a FUJIX BAS1000 phosphorimager (FUJI Medical Systems, USA).

5 Nucleic acid ligand truncation

Truncated versions of full length nucleic acid ligands were generated in three ways. In one method, *E. coli* RNase H and hybrid 2'-OCH₃ RNA/DNA oligonucleotides (**5'N7 cleave, 3'N7 cleave; Table 1**) were used to cleave nucleic acids at a specific site. Truncation SELEX is described in U.S. Patent Application Serial No. 09/275,850, filed March 24, 1999, entitled

10 "Truncation SELEX Method," which is hereby incorporated by reference in its entirety. In a second method, overlapping DNA oligonucleotides encoding the desired ligand sequence were annealed, extended by Klenow DNA polymerase, and then transcribed. In a third method, ligands were chemically synthesized with the desired sequence.

15 Binding of nucleic acid ligands to human TGF β 's

The binding activity of individual ligands was determined by measuring the equilibrium dissociation constants using nitrocellulose partitioning of labeled RNA as a function of protein concentration. RNA was body-labeled or guanylated and then 5'-end labeled with γ -³²P ATP and T4 polynucleotide kinase. Binding reactions were set at various protein concentrations (typically 20 varied in either 3-fold or 10-fold increments) while maintaining the labeled RNA concentration constant at less than 0.1 nM, and incubated at 37°C for 10 minutes. Protein-RNA complexes were partitioned away from uncomplexed RNA, by filtering the binding reactions through a nitrocellulose/cellulose acetate mixed matrix (0.45 μ m pore size filter disks, type HA; Millipore, Co., Bedford, MA). For filtration, the filters were placed onto a vacuum manifold 25 (12-well, Millipore, or 96-well BRL) and wetted by aspirating 1-5 ml of binding buffer. The binding reactions were aspirated through the filters, washed with 1-5 ml of binding buffer and counted in a scintillation counter (Beckmann).

To obtain the monophasic equilibrium dissociation constants of RNA ligands to hTGF β 2 the binding reaction:

30 K_D



R=RNA

P=Protein

K_D =dissociation constant

5 is converted into an equation for the fraction of RNA bound at equilibrium:

$$q = (f/2R_T)(P_T + R_T + K_D - ((P_T + R_T + K_D)^2 - 4P_T R_T)^{1/2})$$

q=fraction of RNA bound

P_T =total protein concentration

R_T =total RNA concentration

10 f =retention efficiency of RNA-protein complexes

The average retention efficiency for RNA-TGF β 2 complexes on nitrocellulose filters is 0.3-0.8.

Kd values were obtained by least square fitting of the data points using the software

Kaleidagraph (Synergy Software, Reading, PA).

15 **Competition between ligands**

^{32}P -labeled test ligands at a concentration of 1 nM were mixed with increasing concentrations of unlabeled NX22283 (SEQ ID NO:114). Then, an amount of TGF β 2 estimated to be near the Kd of the test ligands was added (1 nM for NX22283, 1 nM for 21a-21, 3 nM for 21a-4, and 10 nM for 14i-1). The reactions were incubated, filtered, washed and counted as for a 20 binding reaction.

Off-rate of NX22283

1 nM ^{32}P -labeled NX22283 was mixed with 10 nM TGF β 2, incubated for 5 minutes to allow the protein to bind to the nucleic acid, and then a 1000-fold excess (1 μ M) of unlabeled 25 NX22283 was added. At various time points the reactions were filtered and washed to measure the amount of ^{32}P -labeled NX22283 that remained bound.

Biased SELEX

A library of sequences was constructed based on the sequence of the 34-mer truncate 30 (NX22284) of nucleic acid ligand 21a-21. The sequence of the DNA template (34N7.21a-21

(SEQ ID NO:7)) is shown in **Table 1**. The randomized region is 34 bases long. At each position the randomized region consists of 62.5% of the NX22284 sequence and 12.5% of the other 3 nucleotides. Thus the randomized region is mutagenized at each position (37.5%), but at the same time is biased toward the sequence of NX22284. The fixed regions (5'N7, 3'N7) were the same as used for the primary SELEXs.

To generate **34N7.21a-21 round 0 nucleic acid**, the DNA template was amplified by PCR using the **5'N7** (SEQ ID NO:2) and **3'N7** (SEQ ID NO:3) primers (**Table 1**). This PCR product was transcribed as described above in the filter partitioning SELEX section. This resulted in a **34N7.21a-21 round 0 nucleic acid** pool with the sequence shown in **Table 1** (SEQ ID NO:10).

Filter partitioning as described above and in Fitzwater and Polisky (1996) (Meth. Enz. 267:275-301) with no competitors was used to enrich nucleic acids ligands that bound to human TGF β 2 the best. The protein concentration was reduced from ~150-300 nM to 50 pM. The nucleic acid concentration was reduced from 1 μ M to 1 nM. The nucleic acid/protein ratio ranged from 0.25 to 125. The round 5a pool of ligands was cloned into pUC9 and sequenced as described above.

Bioactivity of TGF β 2 nucleic acid ligands

The bioactivity of TGF β 2 nucleic acid ligands was measured with mink lung epithelial cells. Proliferation of these cells is inhibited by TGF β 2. Human TGF β 2 was titrated on the cells and 3 H-thymidine incorporation was measured. The point at which 3 H-thymidine incorporation by the cells was inhibited by 90-100 % was determined (typically 1-4 pM). This inhibitory amount of TGF β 2 along with varying amounts of nucleic acid ligand (typically 0.3 or 1 nM to 1 or 3 μ M, in 3 fold increments) was used. Typically, cells were plated at 10E5/ml in 96-well plates in 100 μ l MEM, 10 mM HEPES pH 7.4, 0.2% FBS. Following a 4 hour incubation at 37°C, when cells were well attached to the well surface, TGF β 2 was added at 1-4 pM with or without nucleic acid ligands as follows: the ligands were diluted across the 96 well plate in 3-fold dilution steps and then TGF β 2 was added at 1-4 pM to all wells except controls. The cells were incubated for 16-18 hours prior to addition of 3 H-thymidine, and then incubation was continued for 20 additional hours following 3 H-thymidine addition at 0.25 μ Ci per well. After incubation,

the cells were lysed with 1% Triton X-100 and harvested onto GF/B filter plates in a Packard 96 well plate harvester, and 3 H-thymidine incorporation in cellular DNA was quantitated by scintillation counting in MicroScint (Packard, Mariden, CT) in a Packard Top-Count. Data were plotted as % of maximum 3 H-thymidine incorporation vs RNA concentration, and were fitted by 5 the software Kaleidagraph (Synergy Software, Reading, PA) to the equation $m3*(m0+m1+(m2)-((m0+m1+(m2))*(m0+m1+(m2))-4*(m0)*((m2)))^{0.5})/(2*(m2))$; where $m0$ is the concentration of competitor RNA; $m1$ is the IC_{50} , $m2$ is the concentration of $TGF\beta 2$, and $m3$ is the plateau value of the fraction of maximum 3 H-thymidine incorporation. K_i values were determined from IC_{50} values according to the equation $K_i=IC_{50}/(1+([T]/K_{dT}))$, where $[T]$ is the 10 molar concentration of $TGF\beta 2$ present in the assay and K_{dT} is the concentration of $TGF\beta 2$ causing 50% inhibition of MLEC proliferation as determined by $TGF\beta 2$ titration experiments. This assay was also used to determine the isotype specificity of RNA ligands where the three 15 $TGF\beta$ isotypes were independently used as inhibitors of MLEC replication.

15 **Pharmacokinetic properties of NX22323**

The pharmacokinetic properties of $TGF\beta 2$ ligand NX22323 were determined in Sprague-Dawley rats. NX22323 was suspended in sterile PBS and stored at $\leq -20^{\circ}C$. Prior to animal dosing NX22323 was diluted with sterile PBS, to a final concentration of 0.925 mg/ml (18 μM , based on the oligonucleotide molecular weight and the ultraviolet absorption at 260 nm with an 20 extinction coefficient of 0.037 mg of oligo/ml). Sprague-Dawley rats (n=2) were administered a single dose of NX22323 by intravenous bolus injection through the tail vein. Blood samples (approximately 400 μL) were obtained by venipuncture under isofluorane anesthesia and placed in EDTA-containing tubes. The EDTA-treated blood samples were immediately processed by centrifugation to obtain plasma and stored frozen $\leq -20^{\circ}C$. Time points for blood sample 25 collection ranged from 5 to 2880 minutes.

Standards and quality control samples prepared in blank rat plasma and plasma samples were analyzed by a double hybridization assay. To prepare plasma samples for hybridization analysis, 25 μL of plasma sample (or a dilution in plasma of the sample) was added to 100 μL of 30 4 x SSC, 0.5% sarkosyl. A 25 μL aliquot was then mixed with 25 μL of 4 x SSC, 0.5% sarkosyl containing 24 μM capture oligonucleotide conjugated to magnetic beads and 28 μM detect

oligonucleotide conjugated to biotin in a covered 96-well microtiter plates. The mixture was allowed to incubate at 45°C. for 1 hour. Unbound oligonucleotide was removed and 0.1 ng streptavidin alkaline phosphatase/µL NTT Buffer (0.8 M NaCl, 20 mM Tris pH 7.5, 0.5% Tween 20) added to each well followed by a 30 minute incubation at room temperature. The

5 streptavidin alkaline phosphatase was removed and the plate was washed twice with 200 µl NTT Buffer. The NTT Buffer was removed and replaced with 50 µL DEA buffer (0.02% sodium azide, 1 mM MgCl₂, 1% diethanolamine (Tropix, Inc., Bedford, MA), pH 10). Then 34 µL/ml 25 mM chemiluminescent substrate for alkaline phosphatase (Tropix, Inc., Bedford, MA), and 20% Sapphire chemiluminescence amplifier (Tropix, Inc., Bedford, MA) in DEA buffer (50 µL/well) was added. The plate was incubated for 20 minutes at room temperature and read on a luminometer. A standard curve of NX22323 was fit using a variable slope sigmoidal dose response non linear regression equation (PRISM, version 2.00, GraphPad, San Diego, CA). Sample and quality control concentrations were extrapolated from the standard curve and corrected for dilution.

10

15 The average plasma concentration at each time point was calculated and utilized in the pharmacokinetic analysis. Both noncompartmental and compartmental pharmacokinetic analysis were carried out using WinNonlin version 1.5 (Scientific Consulting, Inc.). In the noncompartmental analysis, the following parameters were calculated; the maximum concentration extrapolated at zero time (C_{max}), the area under the curve from zero to the last 20 time point (AUClast), the area under the curve from zero to infinite time (AUC_{INF}), the terminal phase half life (Beta t_{1/2}), the clearance rate (Cl), the mean residence time calculated from zero to infinite time (MRT_{INF}), the volume of distribution at steady state (V_{ss}), and the volume of distribution during elimination (V_z). In the case of compartmental analysis, the following parameters were calculated based on the minimum number of monoexponential equations to 25 adequately fit the data: the maximum concentration extrapolated at zero time (C_{max}), the area under the curve from zero to infinite time (AUC_{INF}), the distribution phase half life (Alpha t_{1/2}), terminal phase half life (Beta t_{1/2}), the exponential constant for the distribution phase (A), the exponential constant for the terminal phase (B), the clearance rate (Cl), the mean residence time calculated from zero to infinite time (MRT_{INF}), and the volume of distribution at steady 30 state (V_{ss}).

EXAMPLE 2. Isolation of Nucleic Acid Ligands That Bind Human TGF β 2

Several SELEX experiments on TGF β 2 have been attempted as summarized in **Figure 1**.

Several partitioning methods were applied at various stages of the SELEX progress including

5 standard filtration through nitrocellulose, spot, surface plasmon resonance biosensor (BIAcore), resonant mirror biosensor (Iasys), polystyrene beads, and polyacrylamide gel shift. The combination of spot SELEX, surface plasmon resonance biosensor SELEX, and filter partitioning SELEX (with competitors) described here had the best overall improvement in affinity (\sim 1000 fold) and thus is described in detail. In addition, a branch of this SELEX that

10 utilized resonant mirror biosensor technology is also described.

Spot SELEX conditions

Spot SELEX was chosen to initiate the SELEX process on human TGF β 2 because it would allow a large amount of protein and nucleic acid to interact. The conditions used are

15 shown in **Table 3**. The results of round 1 were acceptable. The background was very low and the signal to noise ratio was 5. At this point the population from the first round was used for the surface plasmon SELEX in addition to continuing with the spot partition method. Ten rounds of spot SELEX were completed as summarized in **Table 3** and a modest improvement in the affinity of the pool of about 30 fold was observed. These pools were not analyzed further.

20

Surface plasmon resonance biosensor (spr) SELEX

Surface plasmon resonance biosensors were chosen as a partitioning medium because they provide very low background nucleic acid binding to the sensor, so that higher degrees of enrichment can be obtained. In addition binding and elution of nucleic acid can be monitored 25 and quantitated in real time.

TGF β 2 was coupled to a BIAcore biosensor using amine coupling chemistry. TGF β 2 coupled in this manner binds latency-associated protein, and recombinant soluble TGF β receptors. **Figure 2** shows typical sensograms obtained with LAP and recombinant sRIII where we observed k_{on} and k_{off} rates indicative of avid binding. During this SELEX experiment as 30 summarized in **Table 4**, a binding signal was first observed on the biosensor in round 6,

increased up to round 9, and then decreased in rounds 10 and 11. **Figure 3** shows sensograms with 0, 4-spr, 6-spr, 8-spr and 9-spr. **Figure 4** shows typical filter binding curves, in the presence and absence of competitor tRNA, with representative pools from the spr SELEX and from these data it seems that round 9 binds in a biphasic manner with a high affinity and low affinity K_d of 5 30 and 160 nM, respectively.

In bioactivity assays the K_i of the round 0 pool was about 2.6 μ M and the K_i of the round 9-spr pool was about 711 nM (see below). Sequence analysis of representative pools indicated that such pools maintained significant complexity up to round 8 while after round 9 such pools were strongly biased towards a single sequence.

10 Round 8-spr was cloned and sequenced. A total of 69 clones representing 51 different sequences were analyzed. Four sequences (# 8.2, 8.3, 8.9 and 8.48; see **Table 5**) were represented more than once and accounted for 21 of the 69 clones. All four of these sequences bound TGF β 2 and were 2 or 3 base variants of a clone (14i-1) isolated from the filter SELEX (see below). Twenty three other sequences were nonbinding or filter-binding sequences (see 15 **Table 5**) and 25 clones were not tested for binding.

Resonant mirror (rm) optical biosensor SELEX

Since the affinity of nucleic acid pools selected on the surface plasmon resonance biosensor peaked at round 9-spr, resonant mirror (rm) optical biosensor technology was tested to 20 determine if it could advance the affinity of nucleic acid ligands any further. Resonant mirror optical biosensor technology offers many of the same advantage as surface plasmon biosensor technology, but in addition the binding is done in a cuvette under equilibrium conditions rather than over the surface of a chip under flow conditions. Within the cuvette the binding can be extended for long time periods. Therefore the nucleic acid/protein binding reaction can be more 25 stringent and selective.

For resonant mirror SELEX, TGF β 2 was coupled to two biosensor cuvettes using amine coupling chemistry. In one cuvette the TGF β 2 was inactivated by SDS denaturation and this cuvette served to assess background. The other cuvette containing active TGF β 2 was used for the SELEX. Beginning with round 9-spr, five rounds were done using resonant mirror optical

biosensor technology. The conditions used for and the results of the resonant mirror SELEX are shown in **Table 6**.

Biosensor signals were observed for each round. The binding of the nucleic acid pools from rounds 10-rm to 12-rm was assessed (**Table 6**; **Figure 5**). The pool K_d improved modestly 5 up to round 12-rm with no further improvement in the subsequent rounds. The round 12-rm pool binds biphasically with high and low affinity K_d of $\sim 2\text{nM}$ and $\sim 150\text{nM}$, respectively.

In bioactivity assays the K_i of the round 13-rm pool was about 505 nM. Round 13-rm was chosen for subcloning and sequence analysis. Of 15 clones that were sequenced, all 15 (Table 7) were 1 to 5 base variants of a clone (14i-1) which was originally isolated from the filter 10 SELEX (see below).

Filter partitioning SELEX

Round 8-spr was used as the starting material for a filter SELEX. The properties of round 15 8-spr were studied and it was found that 1) a significant fraction bound to a nitrocellulose filter (10%), 2) significant nucleic acid binding (defined here as signal/noise>2) to TGF β 2 was not detectable using nucleic acid-excess conditions, and 3) in the presence or absence of polyanionic competitors there was a significant decrease in the binding of round 0, but not round 8-spr to TGF β 2. These findings had implications that are addressed below.

20 Use of a competitor

The binding of round 8-spr nucleic acid to TGF β 2 in the presence of a polyanionic competitor (yeast tRNA) was studied at various ratios of competitor to nucleic acid. It was found that a 75,000 fold excess of tRNA over round 8-spr nucleic acid resulted in 50% inhibition of binding, whereas a 6,000 fold excess of tRNA over the round 0 nucleic acid pool resulted in 50% 25 inhibition of binding. Heparin also competed with RNA for binding to TGF β 2, but about 10-fold more heparin was needed to inhibit RNA binding to TGF β 2 to the same degree as that observed using tRNA. By including a 100,000-fold excess of yeast tRNA over RNA in a TGF β 2/RNA binding experiment, a 100-fold difference in binding between round 0 and round 8-spr was detected, whereas a 3-fold difference was observed in the absence of any competitor. Thus in the 30 presence of an appropriate amount of competitor, the binding of selected nucleic acid pools is

unaffected, whereas the binding of round 0 nucleic acid is reduced substantially. When competitors are not included in studying the binding of TGF β 2 to nucleic acid the affinity of nucleic acids selected using the SELEX process can be grossly underestimated. In this regard TGF β 2 is similar to other "professional" nucleic acid binding proteins (e.g., restriction enzymes, 5 polymerases, transcription factors, etc.), in that it possesses both a low affinity, nonspecific and a high affinity, specific nucleic acid binding activity. The difference between these 2 binding modes can be revealed in the presence of competitors. Competitors are often used in the study of transcription factors. For example, it can be difficult to detect specific binding of a crude extract containing a transcription factor to oligonucleotides representing their cognate site in gel-shift 10 experiments, unless a competitor, such as poly [dI-dC] • poly [dI-dC], is included in the binding reaction.

Nonspecific binding can involve the binding of multiple proteins per nucleic acid, often at low affinity sites, giving a false appearance of high affinity. A protein can bind at multiple sites on a nucleic acid or protein aggregates may form on a single protein bound to a nucleic acid. 15 TGF β 2 is well known to be "sticky." In the absence of a competitor of nonspecific interactions, TGF β 2 may form large networks and complexes of nucleic acid and protein involving primarily nonspecific interactions. Gel shift analysis of TGF β 2, in the absence of competitor, supports these ideas because TGF β 2 does not form distinct (one to one) complexes with nucleic acid in gels, but instead either remains in the well at the top of a gel or forms smears that may represent 20 large heterogeneous nucleic acid /protein complexes.

Besides the implications for doing binding curves, the nucleic acid -binding properties of TGF β 2 may have implications for SELEX. For example the high level of nonspecific binding of nucleic acid by TGF β 2 may have interfered with previous SELEXs by obscuring specific interactions or preventing the isolation of nucleic acid /protein complexes that involved only 25 specific binding interactions. That is, if mixtures of specific and nonspecific nucleic acid interactions exist in nucleic acid/TGF β 2 complexes that form, then the selection for specific interactions may be difficult, if the nonspecific interactions are not eliminated. Lack of progress in some previous SELEX experiments may have been due to efficient competition by the large excess ($>10^{12}$ - 10^{14}) of low affinity nucleic acids that contain nonspecific binding sites with a

smaller number (~10-1000) of high affinity nucleic acids that contain specific binding sites, especially in early rounds of SELEX.

Use of protein-excess or nucleic acid-excess conditions

Given the discussion above, a question arises as to which type of SELEX condition is better for a protein such as TGF β 2, protein-excess or nucleic acid-excess. Protein-excess conditions may tend to encourage nonspecific interactions. However as long as the competitor/nucleic acid ratio is high enough to eliminate enough nonspecific interactions, but retain specific interactions, this may not be an issue. One advantage to using protein excess is the bound to background ratios are better and background is lower, which would results in better levels of enrichment.

Nucleic acid-excess conditions may not discourage nonspecific interactions because within nucleic acid pools used for SELEX the ratio of nonspecific to specific binding nucleic acids (which is what is most important) would be the same no matter what the nucleic acid concentration is. In addition nucleic acid-excess would reduce the competitor/nucleic acid ratio which would tend to increase nonspecific interactions. As discussed above the ratio of tRNA to nucleic acid must be at least 100,000 in early round of the filter SELEX in order for affinity enrichment to be efficient. This can be technically difficult in early rounds of SELEX when the nucleic acid concentration is typically higher. One advantage to using excess nucleic acid is that more members of a given sequence would be represented in a pool. However if there had been enough enrichment (e. g., using a method such as surface plasmon resonance SELEX) prior to filter SELEX there will probably be multiple representatives of a given sequence and this would not be an issue.

Filter SELEX conditions

The conditions used at each round of the filter SELEX are shown in **Table 15**. Multiple conditions (up to 12) were used in each round varying nucleic acid/protein ratios, competitor/nucleic acid ratios, filter washing buffers, and filter washing volumes. Typically conditions that resulted in the lowest background (<1%) and a significant bound/background ratio (>2) were processed for the next round. Only data for SELEX rounds that were used in the next round are shown in **Table 15**.

The SELEX began by using an amount of tRNA competitor (100,000-fold excess) that was determined *in the SELEX reaction* to inhibit binding of round 8-spr to TGF β 2 by about 60%. SELEX reactions with competitor were done for round 9b through 14i. The inclusion of tRNA in round 9 also dramatically reduced binding of round 8-spr nucleic acid to nitrocellulose filters 5 from ~10-15% to ~1%. The higher the "background" binding is in a SELEX reaction, the lower the maximum possible enrichment. Thus inclusion of tRNA in the early rounds of the filter SELEX may have had a dual benefit. It not only may have eliminated nonspecific binding of TGF β 2 to nucleic acid, but also allowed more enrichment by reducing background. At round 10 15c lower affinity competitors were no longer effective at reducing binding of nucleic acid and were not used. This is presumably because the nucleic acid pool bound TGF β 2 with adequate specificity and affinity. Therefore from round 16 to 22, the presumed specific nucleic acids were 15 allowed to compete with each other by using more traditional nucleic acid -excess conditions.

The background increased to unacceptable levels in rounds 15c and 16a. Gel shift partitioning was investigated as an alternative partitioning procedure at this point but did not 15 work. By modifying the washing conditions the background was reduced to 0.2% in round 17a. After round 18b it was possible to do SELEX rounds at protein concentrations below 1 nM and under nucleic acid-excess conditions. It was also found that nucleic acid concentrations above 1-5 nM also helped to reduce background in some rounds.

In summary, during the filter SELEX, the concentration of the protein was reduced 20 30,000-fold, from 300 nM in round 9b to 10 pM in round 22a. The background binding to filters was reduced from 10% to 0.1%. Nucleic acid pools that bound to TGF β 2 only when protein-excess conditions (~100 protein/1 nucleic acid) were used were selected to bind under high nucleic acid/protein (>100/1) or competitor/ nucleic acid (>10⁷/1)-excess conditions.

Binding of nucleic acid pools from filter SELEX

25 The binding of TGF β 2 to selected nucleic acid pools improved steadily, but slowly and erratically. There was an improvement in the binding of round 10b (K_d =~100 nM) compared to the starting pool (round 8-spr; K_d =~500 nM). The affinity of round 11a was the same as 10b and that of round 12d improved modestly to ~40 nM. Rounds 13i and 15c bound TGF β 2 approximately the same (K_d =~30), while round 14i may have bound worse (K_d =~75). Round 30 16a nucleic acid (K_d =~10 nM) bound slightly better than round 15c. There was ~2-fold

improvement in affinity of the nucleic acid pool from rounds 16a to 17a ($K_d \sim 5$ nM). The K_d of round 18a nucleic acid (~ 5 nM) was equivalent to round 17a nucleic acid. There was another slight increase in affinity from round 18b to 19a ($K_d \sim 2-3$ nM). The affinity of rounds 20a, 21a and 22a plateaued at about 1 nM. The SELEX was stopped at round 22a because the bound to 5 background ratio was below 2 and it would have been technically difficult to reduce the protein concentration to 1-3 pM in round 23.

In summary the K_d improved from ~ 500 nM in round 9b to ~ 1 nM in round 21a, resulting in an overall improvement of ~ 500 -fold in the filter SELEX and $>10,000$ -fold in the entire SELEX. The average improvement per round was only about 1.6-fold. This rate of 10 improvement is slow compared to an average SELEX experiment, which may take ~ 5 rounds using only surface plasmon resonance technology or ~ 10 rounds using only filter partitioning.

Inhibition of bioactivity by nucleic acid pools

Rounds 0, 9-spr, 13-rm, 14i, 18b and 19a, and latency-associated protein (LAP) were 15 tested on mink lung epithelial cells for their ability to reverse TGF β 2-mediated inhibition of 3 H-thymidine incorporation. The results are that the K_i of the round 9-spr pool was about 711 nM. The K_i 's of the round 14i, 18b, 19a and 21a pools were about 231 nM, 309 nM, 154 nM and 10 nM, respectively. The K_i of LAP was about 0.5 nM.

From these results it can be concluded that inhibitors of TGF β 2 were enriched in the later 20 rounds of the TGF β 2 SELEX. In addition there is a continuous correlation between the affinity measured *in vitro* and the inhibitory activity measured *in vivo*:

LAP < round 19A < round 14i < round 13-rm < round 8-spr < round 0.

Sequencing of nucleic acid ligand clones isolated from filter SELEX

25 Based on several criteria (pool K_d , filter-binding background, bound to noise background, inhibitory activity in cell assay, and absence of aberrant products during the RT-PCR steps of SELEX) round 21a was subcloned for sequence analysis. Forty eight clones were sequenced from round 21a (Table 8). Two unique sequences represented by clones 21a-4 and 21a-21 (the first number refers to the SELEX round a clone was initially isolated from and the 30 second number is a clone number) were identified. Several clones were minor variants (1-6

bases different) of clones 21a-4 and 21a-21. One hundred more clones were screened by PCR using primers specific for clones 21a-4 and 21a-21. Of these, 90 were clone 21a-21-like, 9 were clone 21a-4-like and 1 was a third unique sequence (21a-48), which was shown to be a nitrocellulose filter-binding sequence. In conclusion, round 21a consists almost entirely of two sequences and variations of those sequences. This was not surprising because round 21a was the second to last round and the bulk affinity of the nucleic acid pools had not improved much from round 19a to 21a.

5 Since the sequence diversity of round 21a was restricted, 3 other rounds (14i, 16a, 18a) were also sequenced. Only one more novel sequence (14i-1 and variants) was isolated. Two sequences and variations of those sequences. This was not surprising because round 21a was the second to last round and the bulk affinity of the nucleic acid pools had not improved much from round 19a to 21a.

10 filter-binding sequences were also isolated (16a-1 and a variant of 21a-48). Therefore, as with rounds 8-spr, 13-rm and 21a, these 3 rounds also did not contain diverse TGF β 2-binding nucleic acid ligands.

15 The sequences of 14i-1, 21a-4, and 21a-21 are shown in **Table 8**. The affinity of the sequences for human TGF β 2 is about 10 nM, 3 nM and 1 nM respectively. Therefore these 3 sequences are ligands that bind human TGF β 2 with high affinity.

The ligands were tested for inhibitory bioactivity. The K_i 's of 14i-1, 21a-4 and 21a-21 are about 200 nM, 30 nM and 10 nM respectively. Thus these ligands are also inhibitory ligands. As for the pools the binding affinity correlates well with the inhibitory activity. This is not surprising since it is likely the TGF β 2 ligands bind near the heparin binding site which is very close to the TGF β receptor binding region. The inhibitory activity of ligand 21a-21 was also compared to that of antibodies.

20 Clones were isolated and sequenced from six rounds (8-spr, 13-rm, 14i, 16a, 18a and 21a). The number of each type of sequence is summarized **Table 9**. Out of 264 clones analyzed by sequencing and 100 clones analyzed by a PCR-based analysis using ligand-specific primers (Table 10), only 3 different TGF β 2 ligand sequences (and minor variants) were obtained. Fifteen sequences were filter binding sequences and 36 were nucleic acids that do not bind well to filters or TGF β 2. The degree of restriction in sequence diversity observed in this SELEX is very unusual. Generally one can isolate dozens of different nucleic acid ligands and usually it is possible to find high affinity rounds where one ligand represents <10% of the population.

Since sequencing and screening of 6 rounds of SELEX that are as much as 13 rounds apart did not result in a diverse set of sequences the properties of the pools were investigated further to determine where the sequence diversity was restricted. Selected nucleic acid pools were sequenced and semi-quantitative RT-PCR on nucleic acid pools using ligand-specific

5 primers was done. The results are shown in (Table 10). Taken together with the sequencing results, it appears that a restriction in sequence diversity during the SELEX process may have occurred near rounds 6-spr or 7-spr.

Clone 14i-1 is first detectable in round 6-spr, becomes most frequent near round 14i, and decreases in frequency in later rounds. Clone 21a-4 is first detectable by sequencing in round 10 14i, is most abundant in round 16a, and decreases in frequency by round 21a. However 21a-4 may exist in prior rounds (RT-PCR analysis of pools using a primer specific for clone 21a-4 was not done.). Clone 21a-21 was rare in round 14i (<1/104 clones by sequencing; estimate <1/200-500 clones by RT-PCR), became more frequent in round 16a, and composes most of round 18b and 21a.

15 It appears the surface plasmon resonance biosensor SELEX resulted in a high degree of diversity restriction, which has been observed before using this technology. The reason why various later rounds would consist of virtually one sequence is not clear. Perhaps only a very small number of sequences bind TGF β 2 under the selection conditions used. Perhaps a change in selection conditions such as the inclusion of competitors at round 9 or the switch from protein-20 excess binding reactions to nucleic acid-excess binding reactions at round 16 resulted in the emergence of clone 21a-21 as the predominant clone by round 21a. It seems as though the selection pressures were significant because the predominant ligand in a pool changed in as few as 2 rounds.

25 The pattern of changes in the population of nucleic acid ligands can be explained by analogy to the theory of natural selection. In an early SELEX round, a variety of sequences will exist. Strong selective pressure may narrow the sequence variation considerably, to the point that a single sequence is predominant. However rare ligands still exist that can be selected in future rounds or during significant changes in selective pressure. This is true in any SELEX experiment, but the TGF β 2 SELEX experiment described here may be an extreme example. In 30 spite of the restriction on sequence diversity, better binding ligands could eventually be isolated.

Note that ligand 21a-21 was first identified by sequencing in round 16a. Thus rare, high affinity nucleic acid ligands may exist even in round 22 that would only become predominant under the correct selection conditions. One approach for isolating such rare sequences might be to specifically deplete late rounds of SELEX of known sequences (e. g., by hybrid selection,

5 restriction enzyme digestion of PCR products, site-directed RNase H cleavage of nucleic acid), an approach that this TGF β 2 SELEX is well suited for since essentially only 5 different sequences (3 ligands and 2 filter binding sequences) were present in later rounds. Isolating a sequence that is present in <1/1000 clones might be easy using depletion methods, but would be tedious using sequencing or PCR screening methods.

10 These results raise questions about when a SELEX is done and how to judge whether it is done. In this SELEX, standard criteria for judging when a SELEX is done such as K_d improvement, and sequencing of clones or bulk nucleic acid pools may not be good criteria for judging if the SELEX had proceeded as far as it could. Often there are technical limitations (background, reaction volumes, loss of low amounts of protein to large surfaces) that determine 15 when a SELEX must be terminated and these are artificially limiting. Perhaps a "depletion SELEX" round should be done at the end of every SELEX to attempt enrichment of ligands that would be difficult to isolate by currently used methods.

Specificity of human TGF β 2 ligands

20 For nucleic acid ligands to be most useful in the applications claimed herein they should be highly specific for a particular subtype of TGF β . The specificity of human TGF β 2 ligands was investigated by in several ways.

The specificity of TGF β 2 ligands was examined using the cell culture bioactivity assay where the specificity of the TGF β 2 (described here) and TGF β 1 (see U.S. Patent Application 25 Serial No. 09/046,247, filed March 23, 1998, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 6,124,449, which is incorporated herein by reference in its entirety) aptamers was compared to the specificity of antibodies. Two types of antibodies were used namely, monoclonal antibodies and immunopurified polyclonal antibodies. It was found (Figure 6) that the TGF β 2 ligand NX22283 inhibited TGF β 2 protein bioactivity 30 ($K_i=10$ nM), but not TGF β 1 ($K_i>1000$ nM) or TGF β 3 bioactivity ($K_i>1000$ nM). The TGF β 2

ligand NX22283 inhibits the TGF β 2 bioactivity with a potency equivalent to that of a monoclonal antibody while the most potent inhibitor of TGF β 2 bioactivity in this experiment was an *affinity-purified* polyclonal antibody.

The specificity of a TGF β 2 ligand for TGF β 2 compared to TGF β 3 was also analyzed in 5 nucleic acid binding assays. The affinity of round 0 40N7 nucleic acid or the full-length TGF β 2 ligand 21a-21 to human TGF β 2 protein was $>10 \mu\text{M}$ or 1 nM, respectively. The affinity of round 0 nucleic acid or ligand 21a-21 to human TGF β 3 protein was $>10 \mu\text{M}$ or $>30 \mu\text{M}$, respectively. Therefore the TGF β 2 ligand does not bind significantly to TGF β 3.

It was found that the TGF β 1 ligand 40-03 (1 (see U.S. Patent Application Serial No. 10 09/046,247, filed March 23, 1998, entitled "High Affinity TGF β Nucleic Acid Ligands and Inhibitors," now U.S. Patent No. 6,124,449), bound to TGF β 3 although 1000-fold worse. These results indicate there may be one or more amino acids in common between TGF β 1 and TGF β 3 that are not found in TGF β 2 so that a TGF β 1 ligand can bind TGF β 1 and TGF β 3 but not TGF β 2 and so that the TGF β 2 ligand 21a-21 binds TGF β 2 but not TGF β 1 or TGF β 3. Indeed, as shown 15 in **Table 12**, there are 19 amino acids out of 122 that are found in TGF β 2, but not in TGF β 1 or TGF β 3. Three of these differences (Lys-25, Arg-26, and Lys-94 in TGF β 2) are within a putative heparin binding region and may be important for determining the binding specificity of TGF β ligands.

20 **Truncation of nucleic acid ligands**

It is desirable to obtain the smallest "truncate" of a full length nucleic acid ligand so that it can be synthesized efficiently at the least cost. The goal of this study was to obtain ligands that are less than half their original length (<35 bases), yet retain about the same affinity as the full length ligand. Several approaches were used to identify truncates of the three TGF β 2 ligands.

25 RNase H and hybrid 2'-OCH₃ RNA/DNA oligonucleotides (**5'N7 cleave, 3'N7 cleave;** **Table 1**) were used to remove the 5' and 3' fixed sequences from 2'-F pyrimidine, 2'-OH purine nucleic acid ligands as described in U.S. Patent Application Serial No. 09/275,850, filed March 24, 1999, entitled "Truncation SELEX Method," which is hereby incorporated by reference in its entirety.

Second, the "boundaries" of the ligands were identified using a previously described method (Fitzwater and Polisky (1996) Met. in Enzymol. 267:275-301). Boundaries define the 5' and 3' ends of the smallest truncate. However boundary determination does not identify internal deletions that can be made. Also because of the nature of the boundary determination method, if 5 a boundary falls within a run of pyrimidines or is too close to either end, then which nucleotide is the boundary must be determined by other methods (e.g., generation of ligands beginning or ending with each candidate boundary position followed by analysis of their binding to TGF β 2).

10 A third method used relied on plausible structural motifs to define hypothetical sequence boundaries. Synthetic oligonucleotides corresponding to these boundaries were synthesized and were tested for binding to TGF β 2.

15 A fourth approach for identifying TGF β 2 ligand truncates was to look at the location of sequence variations in each ligand. In ligands 21a-4 and 21a-21 the changes that occurred in sequence variants were distributed randomly throughout their sequences. However in ligand 14i-1, the sequence changes in variants were highly localized. This implied that the variable region of ligand 14i-1 could tolerate changes without affecting binding and that the whole variable region may be dispensable.

20 A fifth approach was to make internal deletions based on predicted structures. Portions of putative bulges, loops, or base pair(s) within predicted stems can be deleted. The success of this method depends critically on how close the structural model is to the real structure. For 21a-21 the most stable structure was found to be incorrect. Only when a structure closer to the real structure was identified (by using the biased SELEX method) could internal deletions of 21a-21 successfully be made.

Truncation of ligand 14i-1

25 Using the RNase H truncation method it was determined that ligand 14i-1 requires the 5' but not the 3' fixed sequence (**Table 13**). Consistent with this result, when both the 5' and 3' fixed sequences were removed, ligand 14i-1 did not bind TGF β 2.

30 Conventional boundary experiments defined the 3' end of ligand 14i-1 (**Figure 7**) to be within positions 39-45. In the same experiment we failed to observe a clear boundary at the 5' end of this ligand. Of the 60 sequence variants of ligand 14i-1, 54 have nucleotide changes that

occur within the last 16 bases at the 3' end of the selected sequence region. Most of the variants have single base changes, but a few have as many as 6 bases changed. Such changes may or may not affect binding. If they affect binding then that region is important for binding. More likely, since there are so many changes in so many clones within that region, those bases are probably

5 not important. It was surmised they may be able to be deleted, possibly along with the adjacent 3' fixed region, without affecting binding. This idea was confirmed by two experiments:

1) The binding of 8 sequences that varied within the 16 base region and had different sequence changes was tested. They all bound as well to TGF β 2 as the 14i-1 ligand.

2) A 38 base long truncate of 14i-1 (14i-1t5-41; **Table 13**) that lacked the 3' fixed region and the 10 16 base variable region bound to TGF β 2 as well as the full length (71 base long) ligand.

Four sequences that removed additional bases from the ends of 14i-1 beyond those removed in 14i-1t5-41 were made [(14i-1t5-38, 14i-1t5-35, 14i-1(ML-87), and 14i-1(ML-89)].

Also one internal deletion of 14i-1t5-41 was made [14i-1(ML-86)]. None of these bound to TGF β 2 (**Table 13**). Taken as a whole these experiments showed that the boundaries of ligand

15 14i-1 fall within positions 5-7 at the 5' end and 39-41 at the 3' end. All these results defined a truncate for ligand 14i-1 that is 38 bases long (**Table 13**).

Truncation of ligand 21a-4

Using the RNase H truncation method it was determined that ligand 21a-4 requires the 5' 20 but not the 3' fixed sequence (**Table 14**). When both the 5' and 3' fixed sequences were removed ligand 21a-4 did not bind TGF β 2.

The boundaries of ligand 21a-4 (**Figure 7**) are at positions U11 in the 5' fixed region and within positions 52-56 on the 3' end, defining a truncate that is between 42-46 bases long (**Table 8**). This is consistent with RNase H truncation results which show 21a-4 requires the 5' end but 25 not the 3' end to bind TGF β 2.

By examining hypothetical structures, the boundaries for 21a-4 were predicted to occur at position G12 at the 5' end and position C48 at the 3' end. These positions agree well with the region defined by the boundary method. A 37 base long truncate of 21a-4 (excluding sequences required to initiate transcription), beginning at position 12 and ending at position 48 [(21a-4(ML-30 110); **Table 14**)], bound as well to TGF β 2 as the full length 21a-4 ligand.

One sequence that removes 4 additional bases from the 3' end of 21a-4(ML110) was made that is called 21a-4(ML-111). The binding of 21a-4(ML-111) was reduced 30-fold compared to 21a-4(ML-110). Also three internal deletions of 21a-4(ML-110) were made [21a-4(ML-92, ML-108, and ML-109)]. None of these bound well to TGF β 2 (**Table 14**). A sequence [21a-4(ML-91)] that added 2 bases to the 3' end of 21a-4(ML111) did not have any improved binding compared to 21a-4(ML-110). Thus, the smallest truncate of ligand 21a-4 identified, that retains binding, is 42 bases long.

Truncation of ligand 21a-21

Using the RNase H truncation method it was concluded that ligand 21a-21 requires the 3' but not the 5' fixed sequence (**Table 11**). However, when both the 5' and 3' fixed sequences were removed, ligand 21a-21 bound TGF β 2. This seems paradoxical since removal of the 3' end alone eliminates binding. However, the data can be interpreted to mean that the 3' deletion folds in a structure that does not bind to TGF β 2, while the truncate that lacks both ends does not fold into a dead end structure. Indeed Mfold structure predictions indicate this may be the case.

The boundaries of ligand 21a-21 (**Figure 7**) are at position G21 on the 5' end and within positions 50-55 on the 3' end, defining a truncate that is 30-35 bases long. The results are consistent with RNase H truncation data which shows that 21a-21 requires neither the 5' nor the 3' end to bind TGF β 2. The truncate identified by boundaries falls completely within that defined by RNase H truncation.

Synthetic sequences based on putative structures were also tested as summarized in **Table 11**. Results from these experiments are in agreement with the RNase H and conventional boundary experiments.

Several additional end truncates and internal deletions of 21a-21(ML-95) were made (**Table 11**). The 9 end truncates included 21a-21(ML-96), 21a-21(ML-97), 21a-21(ML-103) 21a-21(ML-104) 21a-21(ML-105), NX22286, NX22301, NX22302, and NX22303. Of these only NX22301, which removes one base at the 5' end, binds as well as 21a-21(ML-95). Internal deletions included 21a-21(ML-99), 21a-21(ML-101), 21a-21(ML-102), 21a-21(ML-114), 21a-21(ML-115), 21a-21(ML-116), 21a-21(ML-118), 21a-21(ML-120), 21a-21(ML-122), 21a-

21(ML-128), 21a-21(ML-132), 21a-21(ML-134), 21a-21(ML-136), and 21a-21(ML-138). Of these 14 internal deletions, only 21a-21(ML-130) bound about as well as 21a-21(ML-95).

Three sequences [21a-21(ML-94), NX22283, and NX22285], were made that are longer than 21a-21(ML-95). Of these only NX22285 may have bound (marginally) better than 21a-

5 21(ML-95). Thus, the shortest ligand identified that binds TGF β 2 is the 34-mer NX22284.

NX22283 and NX22284, which are synthetic analogs of the transcribed ligands 21a-21(ML-94) and 21a-21(ML-95), respectively, bound with identical affinity to TGF β 2 (**Table 11**). The synthetic nucleic acids also have the same inhibitory bioactivity as their transcribed analogs; on the other hand, the short, 30-base long NX22286 and its transcribed analog 21a-21 (ML-96) 10 do not bind TGF β 2 and they do not inhibit TGF β 2 bioactivity. Therefore synthetic nucleic acids have the same properties as their transcribed counterparts.

To summarize, truncated 14i-1, 21a-4, and 21a-21 ligands were identified that bind TGF β 2 as well as the full length ligands and are 38, 37 (excluding 5 bases added to improve transcription yield), and 32 bases long, respectively. Twenty four sequences were made in an 15 attempt to shorten the NX22284 truncated ligand (8 single base deletions and 16 multiple base deletions). Only 2 of them, (21a-21(ML-130) and NX22301, bind to TGF β 2. Therefore it appears that the sequence and spacing of structural elements in NX22284 must be maintained for binding to occur.

20 **Competition between ligands for binding TGF β 2**

Examination of the ability of different ligands to compete with each other for binding to a protein can indicate whether the ligands bind to a similar (or overlapping) or distinctly different regions on the protein.

The ability of NX22283, a truncate of ligand 21a-21 (**Table 14**), to compete with 4 25 ligands (14i-1, 21a-4, 21a-21, and NX22283) was tested. The results were that NX22283 competed best with itself, then with 21a-21, 21a-4, and 14i-1, in decreasing effectiveness. Thus, the ability of NX22283 to compete correlates with how related its sequence is to the sequence of the test ligand. NX22283 is most closely related to itself and competes best with itself. NX22283 is a truncate of 21a-21, and competes with 21a-21 second best. The sequence of 21a-4 may be

distantly related to 21a-21 and NX22283 competes with 21a-4 third best. The sequence of ligand 14i-1 is not related to NX22283, and NX22283 is least capable of competing with 14i-1.

The concentration range of NX22283 required to inhibit 50 % of the binding of the other ligands was 10-fold. Since these differences in the amount of NX22283 it took to compete off 5 the other ligands can be attributed to differences in their affinity there is probably only one type of binding region for these ligands on TGF β 2. However, there may be one or more similar sites per homodimer of TGF β 2. If there were two distinct *types* of nucleic acid binding sites on TGF β 2 (as is the case for the HIV-1 gag protein; Lochrie et al. (1997) Nucleic. Acids Res. 25:2902-2910) it should take >1000 times as much competitor (i.e., the difference between the 10 K_d of round 0 nucleic acid and the K_d of NX22283) to compete off a ligand binding at a second distinct site, because presumably a ligand that has high affinity at one site would have low affinity for a distinct site. This was not observed.

15

Off-rate of NX22283

The half-life for NX22283-TGF β 2 complex was measured in 2 experiments to be 0.5 or 3 minutes. Almost all of the ligand dissociated from TGF β 2 in 60-75 minutes. Although these times may seem short, they are typical of *in vitro* off-rate measurements for nucleic acid ligands 20 that have been isolated by filter partitioning SELEX.

EXAMPLE 3. Nucleic acid ligands isolated by the SELEX method using a biased round 0 library

A biased SELEX is one in which the sequences in a nucleic acid pool are altered to bias 25 the result toward a certain outcome. The primary goals of a "biased" SELEX are to obtain ligands that have a higher affinity and to determine what the putative secondary structure of a ligand may be. The starting, round 0 nucleic acid library (called 34N7.21a-21) used for the TGF β 2 biased SELEX had the same 5' and 3' fixed regions (5'N7 and 3'N7) as the prior TGF β 2 SELEX (Table 1). It was made as a 2'-F pyrimidine, 2'-OH purine nucleic acid. However, as 30 described in the "Materials and Methods" section, the random region was 34 bases long. Within

the randomized region 62.5% of the nucleotides at each position correspond to the NX22284 sequence. The remaining 37.5% correspond to the other three nucleotides. Thus each position is mutagenized and the sequence of the pool is biased toward the NX22284 sequence. Selection for ligands that bind to TGF β 2 using such a pool should allow variants of NX22284 to be isolated,

5 some of which may not have been present in the original 30N7 round 0 pool.

The bulk K_d of the round 0 34N7.21a-21 pool was about 870 nM (**Table 15**) using protein-excess binding conditions. This is at least 10-fold better than for the unbiased round 0 40N7 pool, as would be expected. This round 0 nucleic acid pool also bound under nucleic acid-excess conditions in small scale SELEX type reactions, although poorer than in protein-excess reactions, as would be expected. The progress of the biased SELEX is shown in **Table 15**.

The conditions used in the biased SELEX and the results are shown in **Table 15**. A total of 9 rounds were done. Attempts were made to obtain higher affinity ligands by using competitors, starting at round 4. Both yeast tRNA (low affinity) and NX22284 (high affinity) were used as competitors. Both are nonamplifiable during the PCR step of SELEX. The "A" series was done without competitors while the "B" series was done with competitors.

The binding of the nucleic acid pools to TGF β 2 was measured for rounds 0 to 8 (**Table 15**) and found to improve from ~870 nM for the round 0 nucleic acid library to ~1 nM for the round 5a nucleic acid pool. Competition seemed to have little consistent effect on affinity improvement in this SELEX experiment. Probably competition should have been initiated with

20 NX22284 at round 1. Peak improvement in the pool affinity plateaued in rounds 5, 6 and 7, and 8. Therefore round 5a, the earliest round with the best affinity, was subcloned and sequenced.

Sequences of TGF β 2 nucleic acid ligands obtained from a biased SELEX.

As shown in **Table 16**, 25 unique sequences were obtained. One to nine changes from the starting sequence were found. All of the clones were 34 bases long within the selected sequence, consistent with studies (see "truncation of ligand 21a-21" above) where it was difficult to delete any internal bases.

Covariance between pairs of positions was analyzed by eye and by using the consensus structure matrix program (Davis et al. (1995) Nucleic Acids Research 23:4471-4479).

Covariance was observed between 2 different areas implying the existence of 2 stems in the structure. The pattern of covariance suggests the structural model shown in **Figure 8** or a similar

variant of that structure (e.g., some base pairing could occur within the loop). This predicted structure is the third most stable structure predicted by the Mfold program (Zuker (1989) *Science* 244:48-52). A curious example of possible covariance is observed at positions 15 and 25 in the loop region. A15 and G25 were observed to covary to C15 and U25 in 2 clones (#18 and #29).

5 Ligand 21a-4 also has the C/U combination at the bottom of its putative loop.

Of 34 bases, 11 are "invariant" among these 25 clones (**Table 16**). All of the invariant positions are predicted to occur in the loop and bulge regions except C34, the last nucleotide. The last base of all 3 truncated TGF β 2 ligands (**Figure 8**) is a C. Removal of this C results in loss of binding. If invariant positions indicate regions where TGF β 2 binds the NX22284 ligand, 10 then binding may occur primarily in the bulge and stem loop regions. The stems must be base paired, but can vary in sequence implying that the structure of the stems may be more important than their sequence. The stem may be a structure used to present the bulge, loop and C34 nucleotides in the proper orientation to bind TGF β 2.

Clone 5a-11 from the biased SELEX is similar to clone 21-4 from the primary SELEX, 15 particularly at positions that are invariant in clones from the biased SELEX, thus reinforcing the new structural model and the importance of the invariant positions. It has not been possible to fit ligand 14i-1 into a similar structure. Perhaps it represents a second sequence motif capable of binding TGF β 2.

Binding of nucleic acid ligands isolated from the biased SELEX

20 The binding of clones from the biased SELEX was compared to the binding of full length ligand 21a-21. The majority of the clones bound as well to TGF β 2 as 21a-21 (**Table 16**). One clone (#20) bound about 6-fold worse and one clone (#13) bound about 5-fold better than full length ligand 21a-21. The average K_d of the clones (weighting clones found more than once) is 1.2 nM, which agrees with the round 5a pool K_d of ~1 nM. Thus the ligands that were isolated in 25 this manner were not vastly different in affinity from the starting sequence.

One would expect there to be an optimal number of changes that results in higher affinity ligands. Clones with only a few changes might be expected to bind about the same as the starting sequence, clones with a threshold number of changes may bind better, and clones with too many changes may bind worse. Indeed there may be a correlation between the number of changes and 30 the affinity. Clones with 1 to 4 changes tend to bind the same or worse than ligand 21a-21.

Clones with 5-8 changes tend to bind better than ligand 21a-21. The worst binder (#20) was the one with the most changes (9). The ligand that bound to TGF β 2 the best (clone #13) had 7 changes relative to the starting sequence.

When the clones that bound better and those that bound worse are aligned (**Table 17**) it appears that an A at position 5 may be important for higher affinity binding since the ligands that bind to TGF β 2 best all have an A at position 5 and all clones with an A at position 5 bind at least as well as 21a-21. In contrast clones with a U, C or G at position 5 tend to bind worse than 21a-21. With regard to the pattern of base pair changes in the putative stems there is no single change that correlates with better binding. In addition, the better binders do not consistently have GC-rich stems. However the pattern of changes in the stems of the poor binders does not overlap with that seen in the stems of the better binders. Thus, various stem sequences may result in better binding for subtle reasons.

A point mutant that eliminated binding of the full length 21-21 transcript (21a-21(ML-107); **Table 11**) changes U at position 6 to G. A G was found at position 6 in three clones from the biased SELEX (#4, 9 and 35), one of which (clone #4) has only one other base change while the others had additional changes. All three clones from the biased SELEX that have a G at position 6 bind TGF β 2. Thus it would seem that the U6G change alone eliminates binding, but this binding defect can be reversed when combined with other sequence changes.

To summarize, some changes (such as A at position 5) may act independently and be able to confer better binding alone, while others changes (e.g. at position 6 and in the stems) may influence binding in a more unpredictable way that depends on what other changes are also present.

Presumably sequences that lack an "invariant" nucleotide would not bind to TGF β 2. Some of the invariant bases have been deleted and others have been changed (**Table 11**). None of these 10 altered sequences [21a-4(ML-111); 21a-21(ML-96, 97, 101, 102, 103, 104, 105, 120, NX22286] bind to TGF β 2.

EXAMPLE 4. Substitutions of 2'-OH purines with 2'-OCH₃ purines in NX22284

Substitutions of 2'-OH purines with 2'-OCH₃ purines sometimes results in nucleic acid ligands that have a longer half life in serum and in animals. Since the nucleic acid ligands

described here are ultimately intended for use as diagnostics, therapeutics, imaging or histochemical reagents the maximum number of 2'-OH purines that could be substituted with 2'-OCH₃ purines in ligand NX22284 was determined. NX22284 is a 34-mer truncate of the 70 base long 21a-21TGFβ2 ligand (**Table 18**). NX22284 has 17 2'-OH purines and binds about 2-fold 5 worse than ligand 21a-21.

Initially an all 2'-OCH₃ purine substituted sequence was synthesized (NX22304). Another sequence has all 2'-OH purines substituted with 2'-OCH₃ purines except six purines at its 5' end. Neither bound to TGFβ2 or had measurable bioactivity (**Table 18**).

Therefore a set of sequences was synthesized (NX22356-NX22360; **Table 18**) such that 10 groups of 3 or 4 2'-OH purines were substituted with 2'-OCH₃ purines. The binding of NX22357 was reduced about 2-fold and the bioactivity was reduced 10-fold. The binding and bioactivity of NX22356, NX22358 and NX22360 were unaffected. In contrast the binding of NX22359 was reduced over 100-fold and its bioactivity was reduced over 30-fold. Therefore the sequence of 15 NX22359 was "deconvoluted" one base at a time in order to determine which individual purines in NX22359 cannot be 2'-OCH₃ purines. NX22374, NX22375 and NX22376 are deconvolutions of NX22359. All three of these sequences had greatly reduced binding and bioactivity. This suggests that G20, A22, and A24 cannot be 2'-OCH₃ purines.

NX22377 was designed to determine if a sequence with an intermediate number of 2'-OCH₃ purines could bind TGFβ2 and retain bioactivity. NX22377 has 10 2'-OCH₃ purines out 20 of 17 (representing the 2'-OCH₃ purines in NX22356, NX22357 and NX22360). The binding and bioactivity of NX22377 are identical to NX22284.

NX22417 was designed to test the possibility that G20, A22 and A24 must be 2'-OH purines in order to retain binding and bioactivity. In NX22417 G20, A22 and A24 are 2'-OH purines while the other 14 purines are 2'-OCH₃. NX22417 binds to TGFβ2 as well as NX22284, but its bioactivity is 25 reduced about 10 fold. Since substitution of G20 (NX22374) or A24 (NX22376) alone had a less severe effect than substitution of A22 (NX22375), nucleic acids were synthesized that had all 2'-OCH₃ purines except position A22 (see NX22384) or G20 and A22 (see NX22383). NX22383 and NX22384 did not bind or inhibit TGFβ2, again suggesting that at least 3 purines at positions 20, 22 and 24 must be 2'OH to retain binding and bioactivity.

NX22384 was analyzed by mass spectroscopy to ensure its lack of binding and inhibitory activity was not due to incomplete deprotection or an incorrect sequence. The results are that NX22383 may be 0.5- 0.9 daltons more than the predicted molecular weight and therefore is very likely to be what it should be.

5 Since NX22357 bound to TGF β 2 slightly worse than NX22284, but had a 10-fold reduced bioactivity, it was possible that one or more of the three 2'-OCH₃ purines in NX22357 (G5, A8, A11) may also be required for bioactivity. This notion was tested by synthesizing NX22420 and NX22421. NX22421 has all three of these bases (G5, A8 and A11) as 2'-OH purines (along with G20, A22 and A24, which require 2'-OH groups). NX22420 has A8 (along 10 with G20, A22 and A24) as 2'-OH purines. NX22421 has G5, A8, and A11 (along with G20, A22 and A24) as 2'-OH purines. A8 was retained as a 2'-OH purine in both NX22420 and NX22421 because it was invariant among the clones from the biased SELEX and therefore it was inferred that A8 might be less tolerant to change at the 2' ribose position (as was the case for G20, A22 and A24). Indeed both NX22420 and NX22421 had approximately the same binding 15 and inhibitory activity as NX22284. In summary, the NX22284 sequence can retain maximal binding and inhibitory activity when four purines (A8, G20, A22 and A24) are 2'-OH and the other purines are 2'-OCH₃. Note that all four of these positions were invariant among the clones isolated using the biased SELEX method.

While studies were being done on substituting the 2'-OH purines of NX22284, two 20 shorter versions of NX22284 (21a-21[ML-130] and 21a-21[ML-134]; **Table 11**) were discovered that bound well to TGF β 2 as transcripts. The 2'-OCH₃ purine substitution pattern of NX22420 was transferred to these sequences. NX22426 is the 2'-OCH₃ purine analog of 21a-21(ML-134) and NX22427 is the 2'-OCH₃ purine analog of 21a-21(ML-130). NX22426 bound well to TGF β 2, but had 25-fold reduced bioactivity. NX22427 may have slightly better binding and 25 inhibitory activity than NX22284.

In summary, the human TGF β 2 ligand isolated by using combined spot, spr and filter SELEX methods which have the best combination of affinity, short length, and inhibitory activity is NX22427, a 32-mer with 12 2'-OCH₃ purines out of a total of 16 purines.

Substitutions of 2'-OH purines with 2'-OCH₃ purines in NX22385

Some of the ligands that were isolated using the biased SELEX method (e.g., clone 13) bound better to TGF β 2.

To compare the properties of a truncated clone 13 to truncated 21a-21, NX22385 was synthesized. NX22385 (Table 19) is a 34 base long, 2'-F pyrimidine, 2'-OH purine version of biased SELEX clone #13. It binds about 2.5-fold better than NX22284, the corresponding 34 base long truncate of 21a-21, but its inhibitory activity is about 4-fold worse.

For reasons mentioned in the previous section it was of interest to determine if the properties of a truncated clone 13t when synthesized as a 2'-F pyrimidine, 2'-OCH₃ purine nucleic acid. Two 2'-OCH₃ purine versions of NX22385 (NX22424 and NX22425; Table 19) were synthesized based on the 2'-OCH₃ pattern of NX22420, a truncate of 21a-21. In both nucleic acids A8, G20, A22 and A24 were retained as 2'-OH purines, as in NX22420. In NX22424, the purines that are unique to clone 13 (A5, A6 and G12) are 2'-OH purines. In NX22425, those purines are 2'-OCH₃ purines. Analogs of NX22424 and NX22425 were also synthesized in which A24 (NX22386) or G20 and A24 (NX22387) are 2'-OCH₃ purines. NX22386 and NX22387 were expected to serve as negative controls since 2'-OCH₃ G20 or A24 version of NX22284 were inactive. As expected NX22386 and NX22387 did not bind or inhibit TGF β 2. NX22424 and NX22425 bound to TGF β 2 as well as NX22284, but were reduced >100-fold in bioactivity (Table 19). Therefore, while other sequences that bind as well as NX22284 were isolated, no other sequence was identified that have better bioactivity.

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EXAMPLE 5. Pharmacokinetic properties of NX22323

NX22323 is a 5'-polyethylene glycol-modified version of NX22284 (see Table 11; Figure 9). The plasma concentrations of NX22323 were measured in rats over a 48 hour time period and are shown in Figure 11 with the corresponding pharmacokinetic parameters in Tables 20 and 21. These data demonstrate biphasic clearance of NX22323 from plasma with an initial clearance half life ($\alpha T_{1/2}$) of 1 hour and a terminal clearance half life ($\beta T_{1/2}$) of 8 hours. The volume of distribution at steady state was approximately 140 mL/kg suggesting only minor distribution of the aptamer with the majority remaining in plasma and extracellular water. The clearance rate determined by compartmental analysis was 0.40 mL/(min*kg). This value was consistent with other aptamers with similar chemical composition (5'-PEG 40K, 3'-3' dT, 2'F

pyrimidine, 2'-OH purine nucleic acid). These data support daily administration of NX22323 for efficacy evaluation.

Example 6. 2'-O-Methyl Modification of Lead Truncate Ligand CD70

5 TGF β 1 nucleic acid ligands are disclosed in U.S. Patent Application Serial No. 09/275,850, filed March 24, 1999, entitled "Truncation SELEX Method," which is incorporated herein by reference. A lead aptamer was generated by truncation SELEX by hybridization (see Table 11, Family 4, Ligand #70 in U.S. Patent Application Serial No. 09/275,850), herein called CD70. CD70 derivative oligonucleotides were synthesized containing 2'-OMe modifications at 10 various positions as summarized in Table 22 (SEQ ID NOS:194-216). The results suggest that 13 out of 16 purines can be substituted with their 2'-OMe counterparts without any loss of activity. The molecule with the maximum 2'-OMe modifications (CD70-m13) is also bioactive (Table 22). Figure 10 shows a putative structure of CD70-m13 and the positions of that require the presence of 2'-OH nucleotides. Of interest is the A position at the 3' end of the molecule 15 which according to the proposed structure does not participate in a secondary structure. Deletion of this single stranded A affects somewhat the binding activity of the molecule but it completely eliminates its bioactivity (Table 22). The 2'-OH bases and the 3' final A are in close proximity in the proposed structure. This suggests a domain of the molecule responsible for target binding. Under these circumstances, it is expected that the loop shown at the top of the proposed structure 20 (Figure 10) may not be necessary for binding. This was confirmed by replacing such a loop with a PEG linker and showing that such modified molecules retain binding (Table 22). The PEG linker was conjugated to the aptamer as shown in U.S. Patent Application Serial No. 08/991,743, filed December 16, 1997, entitled "Platelet Derived Growth Factor (PDGF) Nucleic Acid Ligand Complexes," which is hereby incorporated by reference in its entirety. The shortest binding 25 aptamer identified from these experiments is CD70-m22, a 34-mer (including the PEG linker).